PATENT ABSTRACTS OF JAPAN

(11)Publication number : 05-034593
(43)Date of publication of application : 12.02.1993

(51)Int.Cl. G02B 13/24
G02B 13/14
G02B 13/18

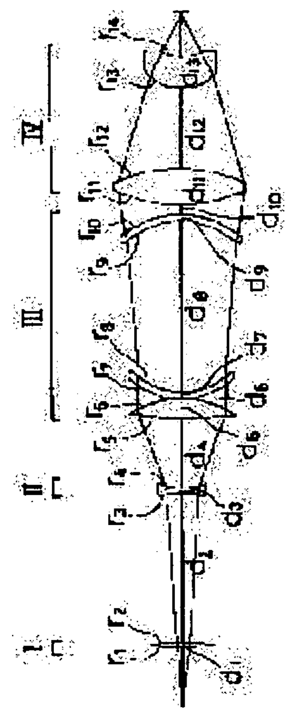
(21)Application number : 03-281223
(22)Date of filing : 28.10.1991

(71)Applicant : OLYMPUS OPTICAL CO LTD
(72)Inventor : KENNO KOKICHI

(30)Priority
Priority number : 03117307 Priority date : 22.05.1991 Priority country : JP

(54) CONTRACTION PROJECTION LENS

(57)Abstract:
PURPOSE: To obtain a both object side/image side telecentric contraction projection lens in which total wall thickness of glass material of a lens system is thin and a transmission factor is satisfactory, and which has a wide exposure area and high resolving power.
CONSTITUTION: This lens is constituted of a first positive lens group I, a second negative lens group II, a third positive lens group III, and a fourth positive lens group IV having at least one piece of meniscus lens whose concave surface is turned to an image side, each lens group is constituted of singular or plural lenses consisting of a glass material whose refractive index is ≤1.6, and also, at least one aspherical surface is placed in a second lens group II and a fourth lens group IV, respectively.



LEGAL STATUS
[Date of request for examination] 17.06.1998
[Date of sending the examiner's decision of rejection] 30.01.2001
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]
[Date of final disposal for application]
[Patent number]
[Date of registration]
[Number of appeal against examiner's decision of

CLAIMS

[Claim(s)]
[Claim 1] In order [side / body], the positive 1st lens group, the negative 2nd lens group, the positive 3rd lens group, It consists of positive 4th lens groups which have at least one meniscus lens which turned a concave surface to an image side. Each lens group is a contraction projection lens characterized by being constituted by an unit or two or more lenses which consist of a with a refractive index of 1.6 or less glass material, and arranging the page [1st / at least] aspheric surface at the 2nd lens group and the 4th lens group, respectively.
[Claim 2] A contraction projection lens according to claim 1 characterized by being constituted by both tele cent rucksack by which an entrance pupil and an exit pupil location were fully set up in the distance.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] Especially this invention relates to the contraction projection lens used in case a circuit pattern etc. is imprinted about a contraction projection lens from the mask on which the circuit pattern was drawn by the reduced-projection-exposure method.
[0002]
[Description of the Prior Art] Generally, the resolution of a projection image with a projection lens is proportional to the numerical aperture, and in inverse proportion to the wavelength to be used. Although resolution will become good and it will go in proportion to it if high integration of a circuit pattern progresses much more, the lens with still more sufficient resolution is required, numerical aperture is enlarged and it goes in recent years, the depth of focus becomes shallow and the necessity of performing focusing very correctly arises. A value also with the very severe display flatness of the silicon wafer which imprints a circuit pattern is required, and it will stop moreover, being fit for practical use.
[0003] Therefore, raising resolution came to be performed in recent years, having shortened operating wavelength and maintaining the depth of focus rather than it enlarges numerical aperture.
[0004] In current, although 365nm light is used from the wavelength of 436nm by the mercury-vapor lamp, there is a proposal of JP,60-140310,A which uses the KrF excimer laser which uses 248nm as an emission spectrum in recent years.
[0005]
[Problem(s) to be Solved by the Invention] By the way, when operating wavelength is set to 250nm or less, the ** material which can be used is permeability to SiO2. Or CaF2 It is SiO2, when it is restricted and processability etc. is moreover taken into consideration. There is no ** material which can carry out deer use. Furthermore, at 200nm or less, it is this SiO2. Even if it uses it, since permeability is low, if ****** thickness is not made below into 200mm order, permeability will become 50% or less. Then, although it becomes a requirement that the ****** thickness of a lens system is shorter, in things, such as above-mentioned JP,60-140310,A, the ****** thickness of a lens system is thicker than 200mm. moreover, there is no change of the projection scale factor produced by the focal error when imprinting a circuit pattern -- as -- an exit pupil location -- substantial -- the image side tele cent of infinite distance -- making it rucksack optical system is known. however, a scale-factor change to which resolution becomes high it is alike and follow, and the still severer thing is required, and change of this projection scale factor does not remain only in an image side, but according to the display flatness of the mask by the side of a body does not break out, either -- as -- a body side tele cent -- rucksack optical system is demanded.
[0006] this invention is made in view of such a condition -- having -- the purpose -- lens system ****** thickness -- below the quadrant of length between object images -- carrying out -- permeability -- good -- carrying out -- in addition -- and it is offering a ****** tele cent rucksack contraction projection lens a body side with a large exposure field and high resolution.
[0007] In addition, in the projection lens of this invention, although the ArF excimer laser which uses 193nm as the main emission spectrums is used, naturally 248nm can be used also in the KrF excimer laser used as the main emission spectrums.
[0008]
[Means for Solving the Problem] In order to attain the above-mentioned purpose, a contraction projection lens of this invention In order [side / body], the positive 1st lens group, the negative 2nd lens group, the positive 3rd lens group, It consists of positive 4th lens groups which have at least one meniscus lens which turned a concave surface to an image side. It is characterized by for each lens group being constituted by an unit or two or more lenses which consist of a with

a refractive index of 1.6 or less glass material, and arranging the page [1st / at least] aspheric surface at the 2nd lens group and the 4th lens group, respectively.

[0009] In this case, it is desirable to be constituted by both tele cent rucksack by which an entrance pupil and an exit pupil location were fully set up in the distance.

[0010]

[Function] Hereafter, the reason and operation which adopted the above configurations are explained. In order to secure high resolution and a large exposure field, it is known well that a curvature of field must be amended nearly completely.

[0011] Moreover, in both the telecentric optical system by the side of a body and an image, it is necessary to project the pupil near a lens system center on infinite distance on the both sides by the side of a body and an image, a positive lens group is allotted near the image near the body, and it is made to carry out image formation of the pupil near a lens system center to the method of infinite distance.

[0012] Furthermore, in order to make the lens system total thickness thin, it is important to reduce the number of the lens elements which need to make one one-sheet lens thin, and constitute each lens group.

[0013] The three above-mentioned requirements have many points which are mutually contradictory. For example, in order to amend a curvature of field and to amend the PETTSU bar sum to ********** zero, **** necessity is near the image near [where MAJINARU light is comparatively low] the body about a negative lens.

[0014] As mentioned above, the conditions of making thin the total thickness of making it both the telecentric system lens and a lens system in order to secure high resolution and a large exposure field turn into a very difficult restriction.

[0015] This invention is made in order to satisfy the restriction which is mutually contradictory as mentioned above, and it explains arrangement and an operation of each group to below.

[0016] In order to make it telecentric optical system, the positive lens system is allotted to the 1st lens group and the 4th lens group.

[0017] The positive power of the 1st lens group is for making small comatic aberration which projects near the 3rd lens group with the strong positive refractive power which exists the entrance pupil of infinite distance in the center of a lens system, and is generated by this 3rd lens group.

[0018] The 2nd lens group serves as a strong negative lens, in order to make high amendment and the light high of the PETTSU bar sum. In order to secure a large exposure field, it is necessary to make it a lens system without a curvature of field, and, for that purpose, generally, making the PETTSU bar sum small is known well. When a strong negative lens system is used, it becomes impossible moreover, to make it balance with the positive spherical aberration which strong negative spherical aberration generates and is generated by other groups. Then, it can amend to still better spherical aberration by using the aspheric surface for the 2nd lens group.

[0019] The 3rd lens group has the work which strengthens negative refractive power of the 2nd lens group. In order to make into the outline parallel flux of light the flux of light from the body which serves as the emission flux of light by the 2nd lens group, the 3rd lens group needs to have positive refractive power, if the positive refractive power of the 3rd lens group is weak, the negative refractive power of the 2nd lens group also becomes weak, and the above-mentioned PETTSU bar sum cannot amend it good.

[0020] The 4th lens groups are both telecentric optical system, and turn into a group which determines the length between object images D and the scale factor beta of the whole system. When it is this invention with few components of a lens system because of this strong positive refractive power, by the spherical-lens system, positive spherical aberration will surely occur. So, in this invention, the spherical aberration generated by the 4th lens group is amended good by using the 1st [at least] page of the aspheric surface also for this 4th lens group. When not using the aspheric surface, even if it is going to amend the spherical aberration generated by the 4th lens group, the number of lens elements is unable to amend by other groups in few lens systems like this invention.

[0021] Moreover, the synthetic focal distance of the 3rd lens group and the 4th lens group is set to f34, and length between object images is set to D. $|f34|<D/5$ ... If it is made to satisfy the conditions of **, a lens system overall length can be made small. When the range of this condition ** is crossed, the distance to which length between object images D is used is exceeded you to be Haruka, the contraction projection aligner using this lens system becomes very large-sized, and it stops being equal to practical use.

[0022] Moreover, since it becomes the group which determines the length between object images D and the scale factor beta of the whole system in both telecentric optical system, the 4th lens group is the focal distance of this group f4 If it carries out $f4 <D/2$ ... It is necessary to satisfy the conditions ** Becoming.

[0023]

[Example] Hereafter, the example of this invention is shown. The cross section of the lens system of examples 1-3 is

shown in drawing 1 - drawing 3 , respectively. Also setting in which example, for the 1st group I, both one convex positive lens to the 2nd group II is both one concave negative lens to the 3rd group III. It consists of a back group of two negative meniscus lenses with which the pre-group of both one convex positive lens and the concave surface faced each other. In an example 1, the 4th group IV consists of two sheets, both the convex positive lens and the positive meniscus lens which turned the concave surface to the image side, consists of three of both two convex positive lenses and the negative meniscus lenses which turned the concave surface to the image side in an example 2, and consists of two sheets, both the convex positive lens and the positive meniscus lens which turned the concave surface to the image side, in an example 3.

[0024] The cross section of the lens system of examples 4-9 is shown in drawing 4 -9, respectively. One positive meniscus lens with which the 1st group I turned the concave surface to the body side also in which example to the 2nd group II is both one concave negative lens to the 3rd group III. It consists of both one convex positive lens. In examples 4 and 7, the 4th group IV consists of two sheets, the positive meniscus lens which turned the concave surface to the image side, and the negative meniscus lens which turned the concave surface to the image side, and consists of two sheets, both the convex positive lens and the negative meniscus lens which turned the concave surface to the image side, in examples 5, 6, 8, and 9.

[0025] About the aspheric surface, it sets in the example 1. The 1st page of the 1st lens group and each 2nd RENSU group, Use for the 6th page of the 1st page of the 3rd lens group, the 4th page, and the 1st page and the last sides of the 4th lens group, and it sets in the example 2. Use for the 5th page of the 1st page of the 1st lens group and each 2nd lens group, the 4th page of the 3rd lens group, and the 1st page and the last sides of the 4th lens group, and it sets in the example 3. It uses for the 7th page of the 1st page of the 1st lens group and each 2nd lens group, the 1st page of the 3rd lens group, the 4th page, the 6th page, and the 1st page and the last sides of the 4th lens group.

[0026] In examples 4-9, it uses for the 3rd page, the 2nd page of the 2nd lens group, the 1st page of the 3rd lens group, and the last side of the 4th lens group, in the example 4. In the example 5 It uses for the 5th page of the 1st page of the 1st lens group, the 2nd lens group, and each 3rd lens group, and the 1st page and the last sides of the 4th lens group. In the example 6 It uses for the 4th page of the 1st page of the 2nd lens group and each 3rd lens group, and the 1st page and the last sides of the 4th lens group. In the example 7 It uses for the 4th page of the 1st page of the 1st lens group, the 2nd lens group, and each 3rd lens group, and the last sides of the 4th lens group. In the example 8 It uses for the 5th page of the 1st page of the 1st lens group, the 2nd page of the 2nd lens group, the 1st page of the 3rd lens group, and the 1st page and the last sides of the 4th lens group, and uses for the 4th page of the 2nd page of the 2nd lens group, the 1st page of the 3rd lens group, and the 1st page and the last sides of the 4th lens group in the example 9.

[0027] In this invention, it is as having described above that amendment of the PETTSU bar sum and amendment of comatic aberration occupy an important location on aberration amendment. Then, the difference between examples 1-3 and examples 4-9 is explained.

[0028] In order to make the PETTSU bar sum small, it is important to make [many] a concave surface with the negative refractive power in a lens system, or to strengthen the refractive power. In the case of examples 1-3, the field with negative refractive power is increased and solved by using the gauss type which required this in ******. In the examples 4-9, by arranging the 3rd lens group III which keeps specified quantity distance from the 2nd lens group II, and has positive refractive power, negative refractive power of the 2nd lens group II was strengthened, and the PETTSU bar sum is amended.

[0029] In addition, about comatic aberration, it is the 3rd lens group III. Examples 1-3 adopted the gauss type which gave the amendment capacity of comatic aberration positively, and it is the 3rd lens group III at examples 4-9. Comatic aberration to generate was made as small as possible, and other lens groups have amended.

[0030] Furthermore, at examples 1-3, it is the focal distance f1 of the 1st lens group I preferably. f1 <D/2.5 ... It is important to satisfy the conditions ** Becoming. It is because the comatic-aberration amendment capacity in the concave surface which the after [the 3rd lens group III] group faced will become low if this maximum is exceeded. The meniscus lens which consisted of this concave surface that faced each other is effective in amending coma flare from the symmetric property of the top flux of light of the light which passes a group after this, and the bottom flux of light. In addition, as for the main thickness of this meniscus lens, it is desirable to carry out from the problem of the permeability of the whole system to 1/4 or less [of an effective diameter]. Furthermore, since the concave surface has faced each other across the pupil location, not generating distortion aberration and astigmatism is known well. Moreover, in order to fully pull out work of each side of the meniscus lens which consisted of this concave surface that faced each other, it is required to make high the light high which passes these meniscus lenses.

[0031] On the other hand, at examples 4-9, it is the focal distance of the 1st lens group I f1 If it carries out D/3<f1 <D ... If it is made the range of the conditions ** Becoming, it is the 3rd lens group III. An entrance pupil is projected on near

and it is the 3rd lens group III. The comatic aberration to generate decreases and a larger exposure field can be secured. If it separates from this condition **, it is the 3rd lens group III. The comatic aberration to generate becomes large, the number of other lens elements will increase and the total thickness of a lens system will benefit amendment of comatic aberration thick.

[0032] Moreover, the 2nd lens group II serves as a strong negative lens for amendment of the PETTSU bar sum. At examples 1-3, it is the focal distance of the 2nd lens group II still more preferably f2 It carries out. |f2 |<D/5 ... It is important to satisfy the conditions ** Becoming. If a negative focal distance is prolonged exceeding the maximum of this condition **, amendment of the PETTSU bar sum will become impossible. In addition, it is the 3rd lens group III because of amendment of this PETTSU bar sum. If negative refractive power of an after group is strengthened, it is the 3rd lens group III. The comatic aberration amended by the after group and generating of coma flare become large, and it becomes impossible to secure a large exposure field.

[0033] The 3rd lens group III constituted from a concave surface which faced each other in the examples 4-9 on the other hand Since there is no after group, if generating of comatic aberration increases too much by the 2nd lens group II, amending by other groups will become difficult. Then, it is the focal distance of the 2nd lens group II f2 It carries out. D/10<|f2 | ... It is important to satisfy the conditions ** Becoming. This conditional-expression ** is convenient for an effect being in amendment of the PETTSU bar sum, and acquiring the flat image surface, if the focal distance of a negative lens is shortened in the examples 4-9 from which a negative lens group turns into only this 2nd lens group II through the whole lens system. However, if the focal distance of the 2nd lens group II becomes short exceeding the minimum of the above-mentioned condition **, the refractive power of a negative lens will become strong too much, and it will have a bad influence on comatic aberration etc. Then, in the case of examples 4-9, they are the 2nd lens group II and the 3rd lens group III instead of there being no concave surface which faced each other. A gap is shortened and it is the 3rd lens group III. The pupil location was established in near, and since it succeeded in stopping low the light high of the chief ray outside a shaft in the 2nd lens group II, the comatic aberration generated by the 2nd lens group II has decreased.

[0034] next -- although the lens data of these examples is shown -- ** material -- all -- fused quartz SiO2 from -- it becomes. A mark is f1, f2, f3, and f4., respectively The focal distance of the 1st lens group thru/or the 4th lens group, f34 is the synthetic focal distance of the 3rd lens group and the 4th lens group, r1, and r2. -- Radius of curvature of each lens side, d1 and d2 For --, the gap between each lens side, n1931, and n1932 -- are the 193nm refractive index of each lens, nu 1, and nu 2. -- is the Abbe number of each lens, and an aspheric surface configuration is expressed with the following formula when the direction which intersects the direction of an optical axis perpendicularly with x and an optical axis is set to y.

[0035]

x=(y2/r)/[1+{1-P(y2/r2)}1/2]

+ For A4y4+A6y6+A8y8+A10 y10, however r, paraxial radius of curvature and P are a constant of the cone, A4, and A6, A8 and A10. It is an aspheric surface coefficient.

[0036] In addition, the scale factor of each example sets 1000mm and an exposure field to one fifth, numerical aperture NA sets 0.45 and length between object images D in the examples 1, 2, 4-9, and it is 15x15mm in 10x10mm and an example 3. moreover -- a focal distance -- the projection lens of this invention -- a body side and an image side -- both the tele cent -- since it is a rucksack lens system, any example is infinite.

[0037] Example 1r1 = 451.692 (aspheric surface) d1 = 6.713 n1931 =1.56 (SiO2) nu1=67.8r2 =-288.953 d2 = 217.576 r3 = -91.166 (aspheric surface) d3 = 5.000 n1932 =1.56 (SiO2) nu2=67.8r4 = 91.869 d4 = 101.863 r5 = 735.532 (aspheric surface) d5 = 26.997 n1933 =1.56 (SiO2) nu3=67.8r6 =-136.072 d6 = 0.339 r7 = 108.940 d7 = 8.578 n1934=1.56 (SiO2) nu4=67.8r8 = 97.643 (aspheric surface) d8= 245.090 r9 =-118.470 d9= 9.457 n1935 =1.56(SiO2) nu5=67.8r10=-139.413 d10= 14.230 r11= 248.505 (aspheric surface) d11= 49.436 n1936 =1.56 (SiO2) nu6=67.8r12=-228.156 d12= 114.603 r13= 67.874 d13= 44.827 n1937 =1.56 (SiO2) nu7=67.8r14= 75.136 (aspheric surface) The aspheric surface coefficient 1st page P = 1 A4 = 2.93249x10-8A6 = -6.01561x10-13A8 = 7.75262x10-17 A10 =-1.59422x10-20 The 3rd page P = 1 A4 = 1.70739x10-7A6 = -9.00445x10-12A8 = [-1.88095x10-16] The A10 =3.32351x10-18 5th page P = 1 A4 = [3.77679x10-9A6] = 1.18388x10-13 A8 =-6.91515x10-17 A10 = 1.78302x10-21 The 8th page P = 1 A4 = [2.24951x10-8A6] = 5.83034x10-13 A8 = 1.81963x10-17 A10 = 3.58875x10-21 The 11th page P = 1 A4 = [-2.18203x10-8A6] =-5.58764x10-13 A8 =-3.39369x10-18 A10 = 4.26460x10-22 The 14th page P = 1 A4 = [4.78744x10-7A6] = 9.95229x10-11 A8 3 = 219.905 f = 1.82581x10-14 A10 = 9.52854x10-18 f1 = 315.709f2 =-80.917f 4 = 152.611f 34= 608.503 .

[0038] Example 2r1 = 346.678 (aspheric surface) d1 = 8.996 n193 = 1.56 (SiO2) nu =67.8r2 =-211.745 d2 = 116.945 r3 = -84.931 (aspheric surface) d3 = 5.000 n193 = 1.56 (SiO2) nu =67.8r4 = 92.254 d4 = 73.419 r5 = 690.064 d5 = 18.505

n193 = 1.56 (SiO2) nu =67.8r6 =-118.105 d6 = 221.548 r7 = 110.508 d7 = 6.107 n193 =1.56 (SiO2) nu =67.8r8 = 94.010 (aspheric surface) d8= 215.600 r9 =-116.782 d9= 5.000n193 =1.56(SiO2) nu =67.8r10=-135.508 d10= 0.100 r11= 254.527 (aspheric surface) d11= 12.600 n193 = 1.56 (SiO2) nu=67.8r12=-7731.132 d12= 0.100r13= 321.598 d13= 38.382 n193 = 1.56 (SiO2) nu =67.8r14=-249.389 d14= 97.319 r15= 54.043 d15= 46.683 n193 =1.56(SiO2) nu =67.8r16= 45.969 (aspheric surface) The aspheric surface coefficient 1st page P = 1 A4 = [3.50944x10-8A6] =-1.17311x10-12 A8 =-9.39000x10-17 A10 = -1.18581x10-20 The 3rd page P = 1 A4 = [1.51045x10-7A6] = 3.15495x10-11 A8 = 7.17742x10-15 A10 = The 1.17334x10-18 8th page P = 1 A4 = [2.41442x10-8A6] =-1.37501x10-13 A8 =-3.82684x10-17 A10 = -4.07941x10-21 The 11th page P = 1 A4 = [-2.85336x10-8A6] =-9.27780x10-13 A8 =-9.61658x10-18 A10 = 5.57595x10-22 The 16th page P = 1 A4 = [1.69376x10-6A6] = 1.04389x10-9A8 = 4.87186x10-13 A10 = 7.55304x10-16 fl = 236.105f2 =-78.173f3 = 150.720f4= 114.477f34=-147.329.

[0039] Example 3r1 = 226.862 (aspheric surface) d1 = 21.097 n193 = 1.56 (SiO2) nu =67.8r2 =-331.243 d2 = 156.694 r3 = -74.083 (aspheric surface) d3 = 84.138 n193 = 1.56 (SiO2) nu =67.8r4 = 84.138 d4 = 104.086 r5 = 652.171 (aspheric surface) d5 = 28.328 n193 = 1.56 (SiO2) nu =67.8r6 =-137.525 d6 = 20.895 r7 = 117.445 d7 = 5.000 n193 =1.56 (SiO2) nu =67.8r8 = 103.697 (aspheric surface) d8= 236.472 r9 =-128.167 d9= 6.469n193 =1.56(SiO2) nu =67.8r10=-154.631 (aspheric surface) d10= 6.469r11= 190.291 (aspheric surface) d11= 22.633 n193 = 1.56 (SiO2) nu =67.8r12=-308.181 d12= 117.017r13= 68.215 d13= 49.275 n193 =1.56 (SiO2) nu = 67.8r14= 87.724 (aspheric surface) The aspheric surface coefficient 1st page P = 1 A4 = 1.01346x10-8A6 = -6.39640x10-13A8 =-1.03771x10-17 A10 =-3.19138x10-22 The 3rd page P = 1 A4= 3.88528x10-7A6 = 3.09256x10-11A8 = 3.92110x10-15 A10 = The 2.74269x10-18 5th page P = 1 A4 = [4.35316x10-9A6] =-9.04323x10-13 A8 = 9.26304x10-17 A10 = -6.78193x10-21 The 8th page P = 1 A4 = [1.82229x10-8A6] =-2.70904x10-13 A8 = 1.92104x10-17 A10 = 7.81170x10-21 The 10th page P = 1 A4 = [-9.39398x10-10] A6 = [-7.71154x10-14] A8 = [-2.42008x10-18] A10 =-1.25911x10-21 The 11th page P = 1 A4 = -2.21247x10-8A6 = -6.04358x10-13A8 =-1.70217x10-17 A10 = 3.49063x10-22 The 14th page P = 1 A4 = 6.77267x10-7A6 = 1.17636x10-10A8 3 = 220.394 f = 2.34623x10-14 A10 = 1.16254x10-17 fl = 243.746f2 =-59.072f 4 = 162.576f 34= 671.921 .

[0040] Example 4r1 =-572.0476 d1 = 10.000 n1931 =1.56 (SiO2) nu1=67.8r2 =-184.8433 d2 = 409.771 r3 =-458.4715 d3 = 10.000 n1932 =1.56 (SiO2) nu2=67.8r4 = 202.4878 (aspheric surface) d4 = 190.139 r5 = 286.1623 (aspheric surface) d5 = 45.952 n1933 =1.56 (SiO2) nu3=67.8r6=-214.2468 d6 = 45.952 r7 = 187.2298 d7 = 29.313 n1934 =1.56 (SiO2) nu4=67.8r8 = 2521.0651 d8 = 97.435r9 = 69.7454 d9 = 44.735 n1935 =1.56 (SiO2) nu5=67.8r10=42.0656 (aspheric surface) The aspheric surface coefficient 4th page P = 1 A4 = 1.59538x10-7A6 = 8.3103x10-12A8 = 5.1193 x10-16 A10 =-3.9590 x10-20 The 5th page P = 1 A4 = -3.72611x10-8A6 = 6.90136x10-14A8 = 7.79908x10-18 A10 =-1.74025x10-22 The 10th page P = 1 A4 = [9.15018x10-7A6] = 6.01403x10-10 A8 4 = 425.39731 f = 1.35777x10-13 A10 = 5.31287x10-16 fl = 483.16993f2 =-249.45725f3 = 226.24081f 34= 105.47071 .

[0041] Example 5r1 =-541.2251 (aspheric surface) d1 = 10.000 n1931 =1.56 (SiO2) nu1=67.8r2 =-178.508 d2 = 380.563 r3 =-116.7046 (aspheric surface) d3 = 10.000 n1932 =1.56 (SiO2) nu2=67.8r4 = 167.246 d4 = 88.289 r5 = 493.1745 (aspheric surface) d5 = 31.836 n1933 =1.56 (SiO2) nu3=67.8r6 =-167.779 d6 = 152.364 r7 = 171.5560 (aspheric surface) d7= 39.607 n1934 =1.56(SiO2) nu4=67.8r8 =-486.272 d8= 114.281 r9 = 62.349 d9 = 48.557 n1935 =1.56(SiO2) nu5=67.8r10= 47.5491 (aspheric surface) The aspheric surface coefficient 1st page P = 1 A4 = [2.03175x10-8A6] = 3.10104x10-13 A8 = 3.35603x10-17A10 = -1.06665x10-20 The 3rd page P = 1 A4 = [-8.73843x10-8A6] = 2.43775x10-12 A8= 3.77550x10-16 A10 =1.31565x10-19 5th page P= 1 A4 = -1.65516x10-8A6 = -4.46539x10-13A8 = [3.83871x10-17A10] = -1.09113x10-21 The 7th page P = 1 A4 = [-2.77045x10-8A6] =-6.49105x10-13 A8 =-1.28276x10-17 A10 = -3.27926x10-22 The 10th page P = 1 A4 = [1.06582x10-6A6] = 5.51608x10-10 A8 4 = 163.54116 f = 2.17457x10-13 A10 = 2.85959x10-16 fl = 470.98184f2 =-121.21548f3 = 227.48599f 34= 134.92856 .

[0042] Example 6r1 =-639.5688 d1 = 10.000 n1931 =1.56 (SiO2) nu1=67.8r2 =-172.8565 d2 = 336.346 r3 =-117.7121 (aspheric surface) d3 = 10.000 n1932 =1.56 (SiO2) nu2=67.8r4 = 138.9428 d4 = 86.675 r5 = 428.5867 (aspheric surface) d5 = 28.263 n1933 =1.56 (SiO2) nu3=67.8r6=-173.7725 d6 = 167.149 r7 = 160.0200 (aspheric surface) d7 = 35.5094 n1934 =1.56(SiO2) nu4=67.8r8 =-583.8214 d8= 101.926 r9 = 65.1302 d9 = 56.228 n1935 =1.56(SiO2) nu5=67.8r10= 50.5856 (aspheric surface) The aspheric surface coefficient 3rd page P = 1 A4 = [-4.97515x10-8A6] = 1.00710x10-11 A8 = 5.58840x10-16 A10 = 2.85451x10-19 The 5th page P = 1 A4 = [-9.69048x10-9A6] =-7.78872x10-13 A8 = 5.68133x10-17 A10 = -1.88990x10-21 The 7th page P = 1 A4 = [-3.18894x10-8A6] =-7.74915x10-13 A8 =-2.05000x10-17 A10 = -7.26451x10-22 The 10th page P = 1 A4 = [1.18566x10-6A6] = 5.38757x10-10 A8 4 = 151.85925 f = 2.21170x10-13 A10 = 1.78106x10-16 fl = 419.75575f2 =-112.22444f3 = 224.57070f 34= 140.86807 .

[0043] Example 7r1 =-177.6669 (aspheric surface) d1 = 10.000 n1931 =1.56 (SiO2) nu1=67.8r2 =-114.2492 d2 = 419.764 r3 =-340.0667 (aspheric surface) d3 = 10.000 n1932 =1.56 (SiO2) nu2=67.8r4 = 147.5802 d4 = 94.540 r5 = 316.7103 (aspheric surface) d5 = 36.042 n1933 =1.56 (SiO2) nu3=67.8r6 =-150.7398 d6 = 229.790 r7 = 142.6463 d7 = 19.393 n1934 =1.56 (SiO2) nu4=67.8r8 = 2500.1875 d8 = 32.167 r9 = 60.8011 d9 = 64.565 n1935 = 1.56(SiO2) nu5=67.8r10= 38.4152 (aspheric surface) The aspheric surface coefficient 1st page P = 1 A4 = [2.96198x10-8A6] = 2.80539x10-12 A8 = 3.32053x10-16A10 = -3.12952x10-20 The 3rd page P = 1 A4 = [-1.53160x10-7A6] =- 7.02996x10-12 A8 =-6.64599x10-16 A10 = -2.96550x10-20 The 5th page P= 1 A4 = [-3.63247x10-8A6] =- 3.24021x10-13 A8 = 2.73201x10-17 A10 = -5.07985x10-22 The 10th page P = 1 A4 = [2.72286x10-6A6] = 2.66106x10-9A8 = 4 = 163.65149 f 1.32154x10-12 A10 = 6.12735x10-15 f1 = 540.93912f2 =-182.43733f3 = 187.56708f 34= 144.89599 .

[0044] Example 8r1 =-770.5823 (aspheric surface) d1 = 10.000 n1931 =1.56 (SiO2) nu1=67.8r2 =-181.1563 d2 = 323.852 r3 =-104.2579 d3 = 10.000 n1932 =1.56 (SiO2) nu2=67.8r4 = 152.4160 (aspheric surface) d4 = 83.320 r5 = 687.3939 (aspheric surface) d5 = 27.073 n1933 =1.56 (SiO2) nu3=67.8r6 =-152.2819 d6 = 199.438 r7 = 165.5278 (aspheric surface) d7 = 37.254n1934 =1.56(SiO2) nu4=67.8r8 =-521.4727 d8 = 110.829r9 = 64.7358 d9 = 55.673 n1935 =1.56 (SiO2) nu5=67.8r10=51.6125 (aspheric surface) The aspheric surface coefficient 1st page P = 1 A4 = 1.33179x10-8A6 = 1.51140x10-13A8 = [-4.98385x10-17] A10 = 7.93760x10-21 The 4th page P = 1 A4 = 2.63093x10-8A6 = -8.62168x10-12A8 =-5.04964x10-16 A10 = 5.54964x10-20 The 5th page P = 1 A4=-1.75977x10-8A6 = -2.26585x10-14A8 = 7.86457x10-18 A10 =-2.01203x10-22 The 7th page P = 1 A4 = -2.71075x10-8A6 = - 6.98608x10-13A8 = [-1.54543x10-17] A10 =-4.67852x10-22 The 10th page P = 1 A4 = 1.20203x10-6A6 = 5.58619x10-10A8 = 1.88633x10-13 A10 = 2.53098x10-16 f1 = 420.35709f2 = 3 = -109.02802f225.22159 4 = 152.37870 ff 34= 167.04208 .

[0045] Example 9r1 =-689.8204 d1 = 10.000 n1931 =1.56 (SiO2) nu1=67.8r2 =-175.7935 d2 = 335.963 r3 =-117.2918 d3 = 10.000 n1932 =1.56 (SiO2) nu2=67.8r4 = 133.7268 (aspheric surface) d4 = 85.589 r5 = 489.8047 (aspheric surface) d5 = 28.595 n1933 =1.56 (SiO2) nu3=67.8r6=-164.6619 d6 = 165.824 r7 = 164.5730 (aspheric surface) d7 = 36.401 n1934 =1.56(SiO2) nu4=67.8r8 =-519.6006 d8 = 102.620r9 = 65.0957 d9 = 55.004 n1935 =1.56 (SiO2) nu5=67.8r10=51.1461 (aspheric surface) The aspheric surface coefficient 4th page P = 1 A4 = 4.70544x10-8A6 = - 9.70520x10-12A8 = [-7.80392x10-16] A10 = 5.09643x10-20 The 5th page P = 1 A4 = -1.03988x10-8A6 = - 2.91909x10-13A8 = 8.42545x10-18 A10 =-3.31289x10-23 The 7th page P = 1 A4 = [-2.93977x10-8A6] =- 7.99535x10-13 A8 =-1.74429x10-17 A10 = -4.57788x10-22 The 10th page P = 1 A4 = [1.13344x10-6A6] = 5.02843x10-10 A8 4 = 152.68722 f = 1.71824x10-13 A10 = 1.87329x10-16 f1 = 418.35278f2 =-110.00832f3 = 223.56611f 34= 141.63892 .

[0046] Aberration drawing showing the spherical aberration of the above examples 1-3, astigmatism, distortion aberration, and transverse aberration is shown in drawing 10 - drawing 18 . Among drawing, in Y, an image quantity ratio and M show the meridional image surface, and S shows the sagittal image surface.

[0047]

[Effect of the Invention] a body side with the permeability with a large exposure field and high resolution sufficient as explained above according to this invention, and an image side -- both -- a tele cent -- the contraction projection lens of a rucksack configuration can be obtained.

[Translation done.]

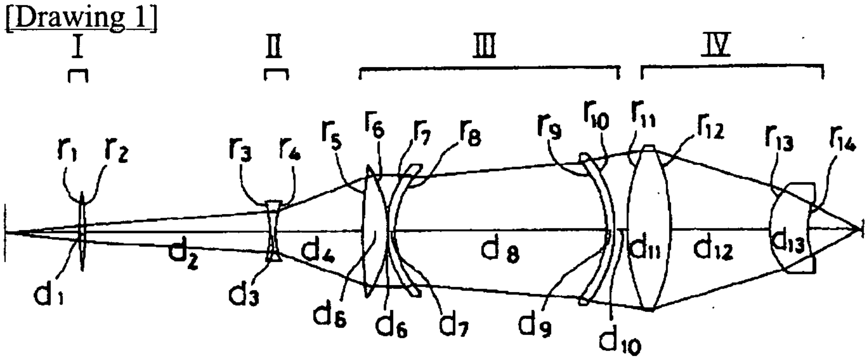
* NOTICES *

Japan Patent Office is not responsible for any damages caused by the use of this translation.

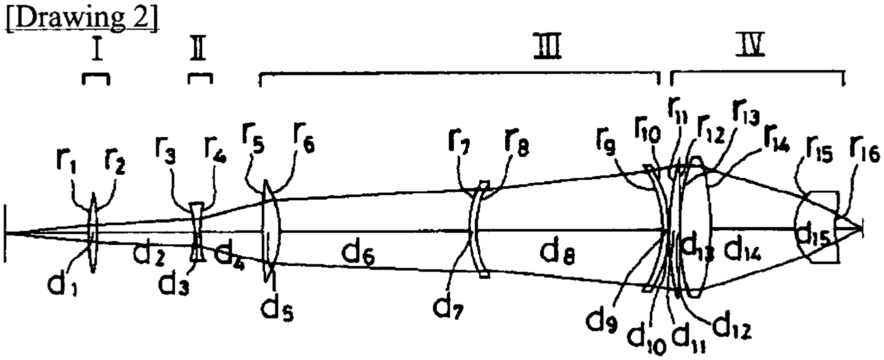
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

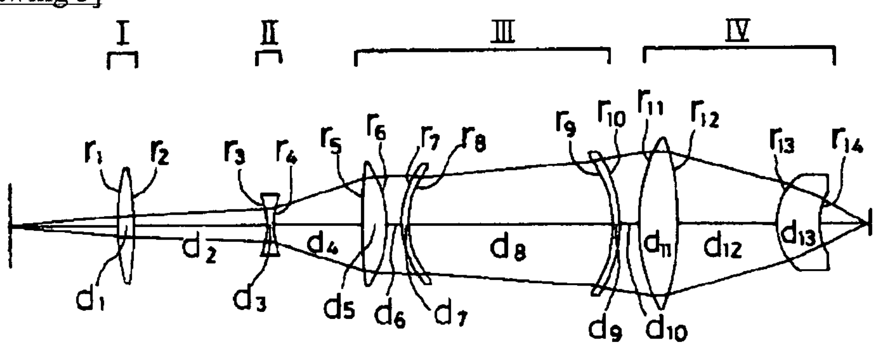
[Drawing 1]



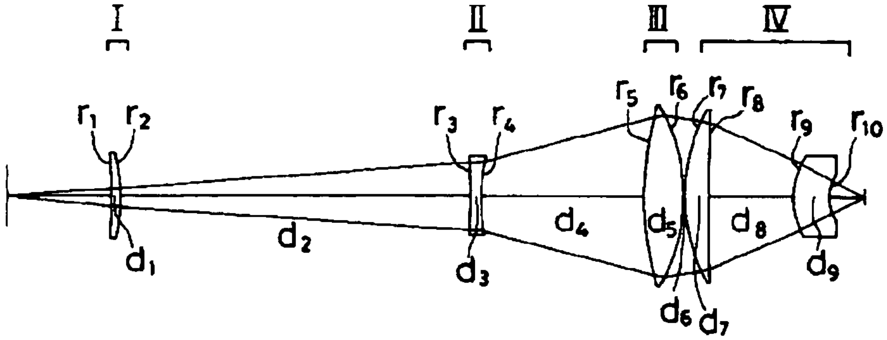
[Drawing 2]



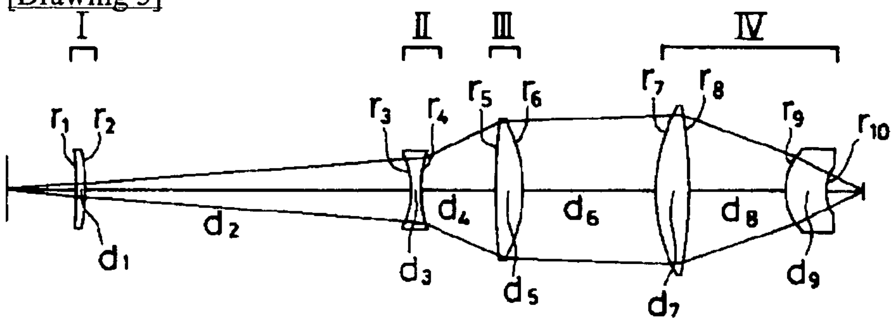
[Drawing 3]



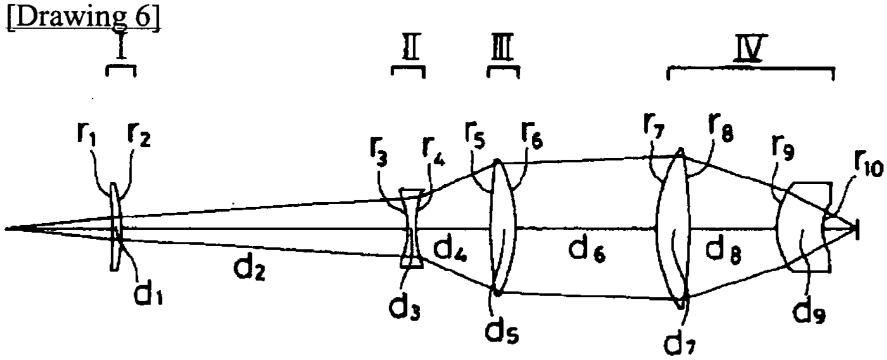
[Drawing 4]



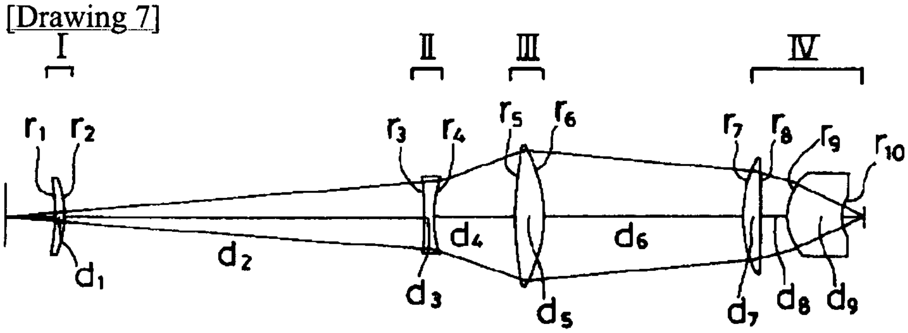
[Drawing 5]



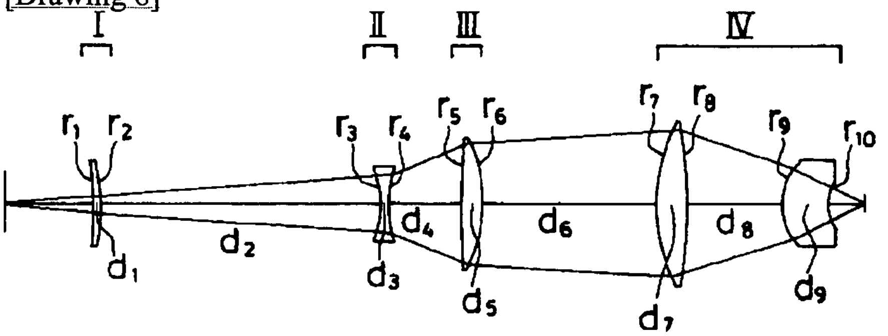
[Drawing 6]



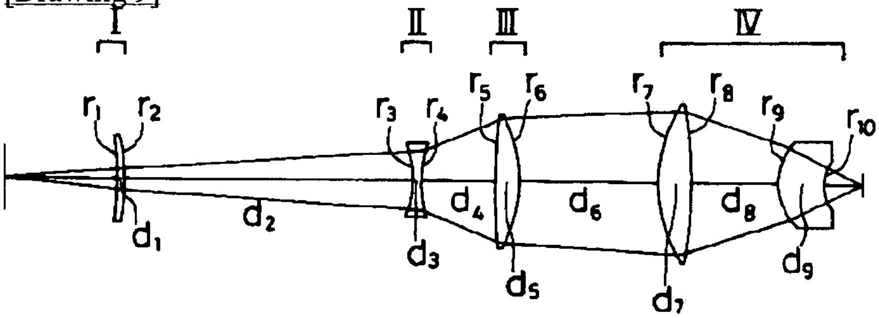
[Drawing 7]



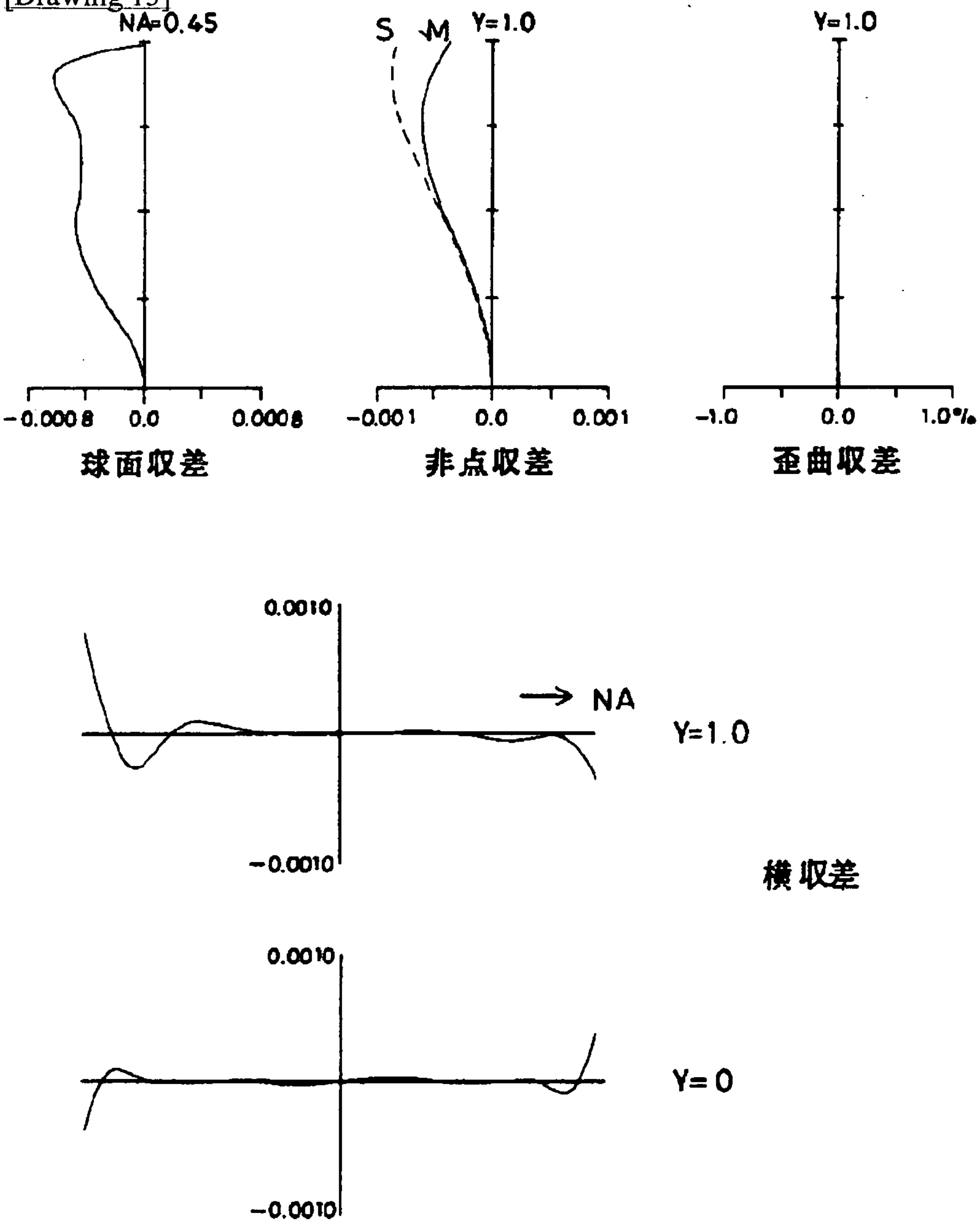
[Drawing 8]



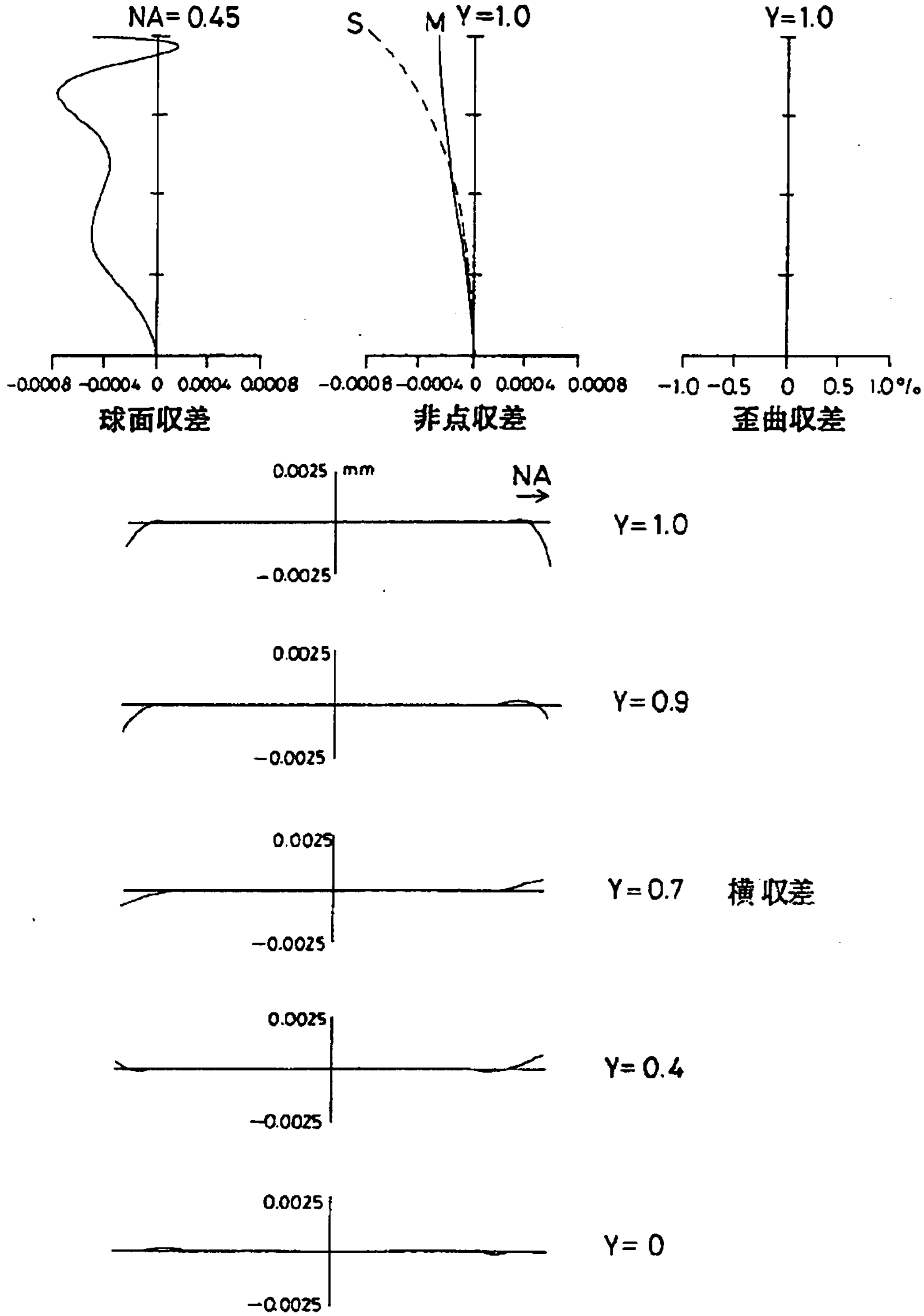
[Drawing 9]



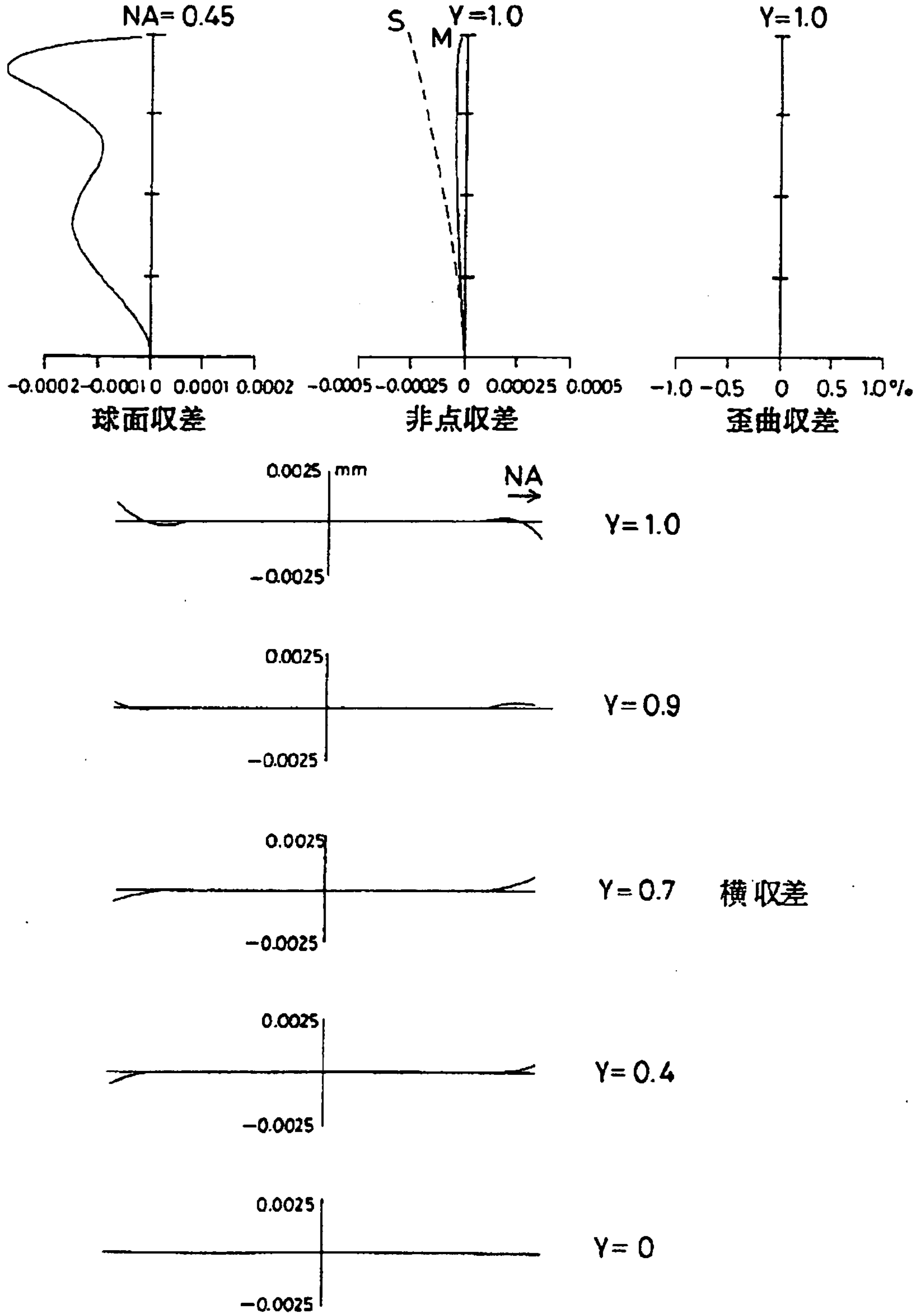
[Drawing 13]



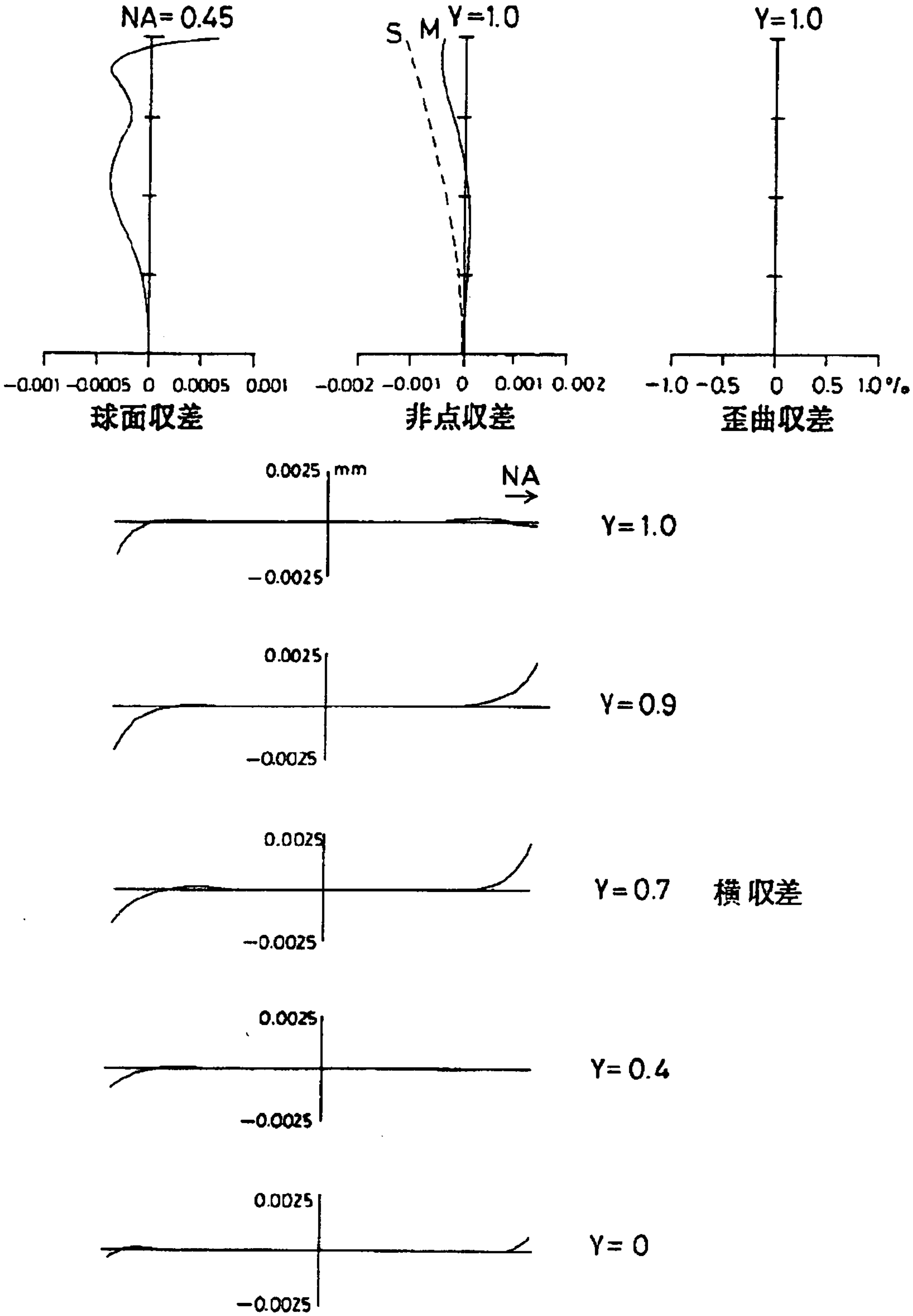
[Drawing 10]


NA= 0.45
S
M
Y=1.0
Y=1.0
-0.0008 -0.0004 0 0.0004 0.0008
球面収差
-0.0008 -0.0004 0 0.0004 0.0008
非点収差
-1.0 -0.5 0 0.5 1.0%
歪曲収差
0.0025 mm
NA
-0.0025
Y= 1.0
0.0025
-0.0025
Y= 0.9
0.0025
-0.0025
Y= 0.7
横収差
0.0025
-0.0025
Y= 0.4
0.0025
-0.0025
Y= 0

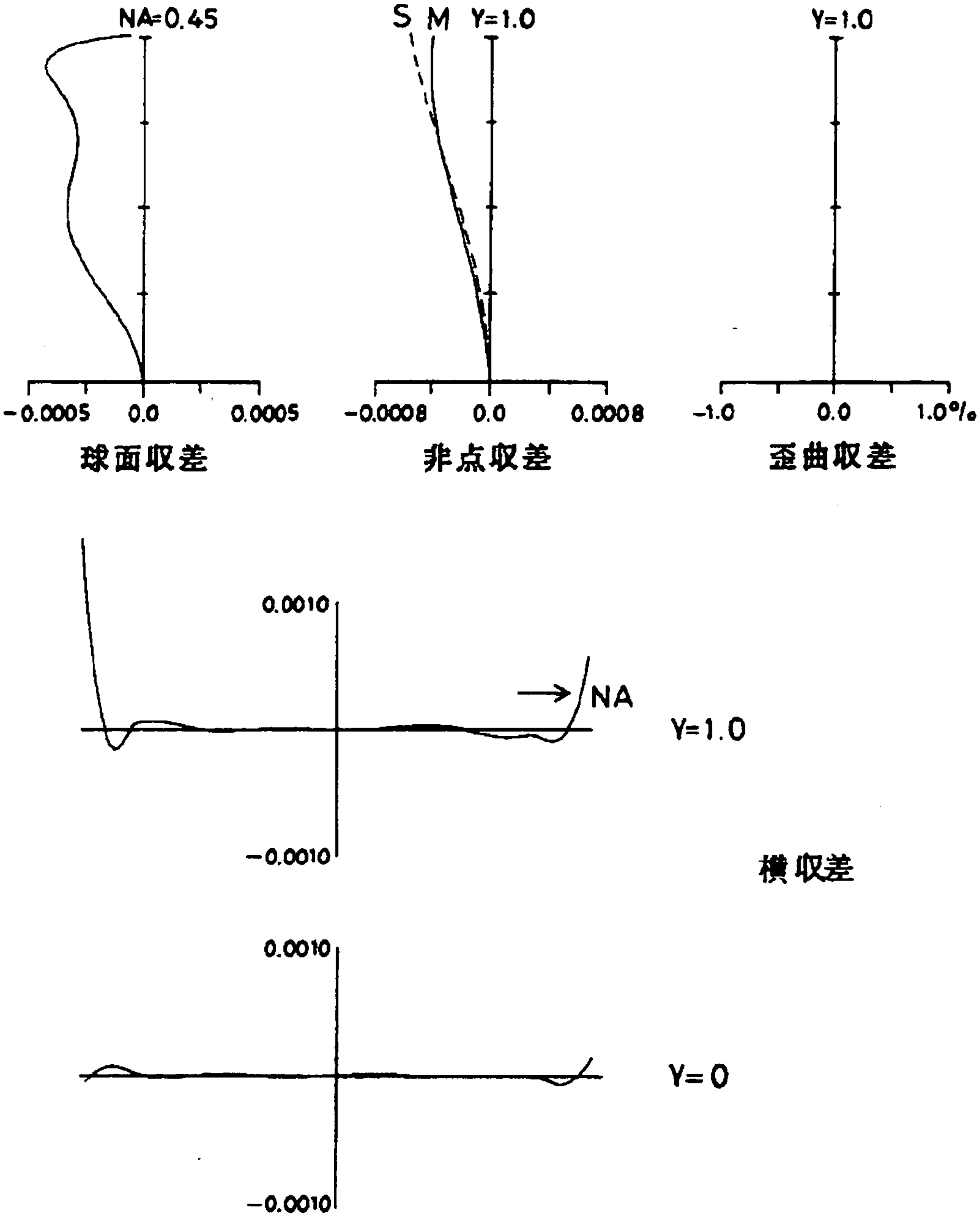
[Drawing 11]


NA= 0.45
-0.0002 -0.0001 0 0.0001 0.0002
球面収差
S
M
Y=1.0
-0.0005 -0.00025 0 0.00025 0.0005
非点収差
Y=1.0
-1.0 -0.5 0 0.5 1.0%
歪曲収差
0.0025 mm
NA
-0.0025
Y=1.0
Y=0.9
Y=0.7
横収差
Y=0.4
Y=0

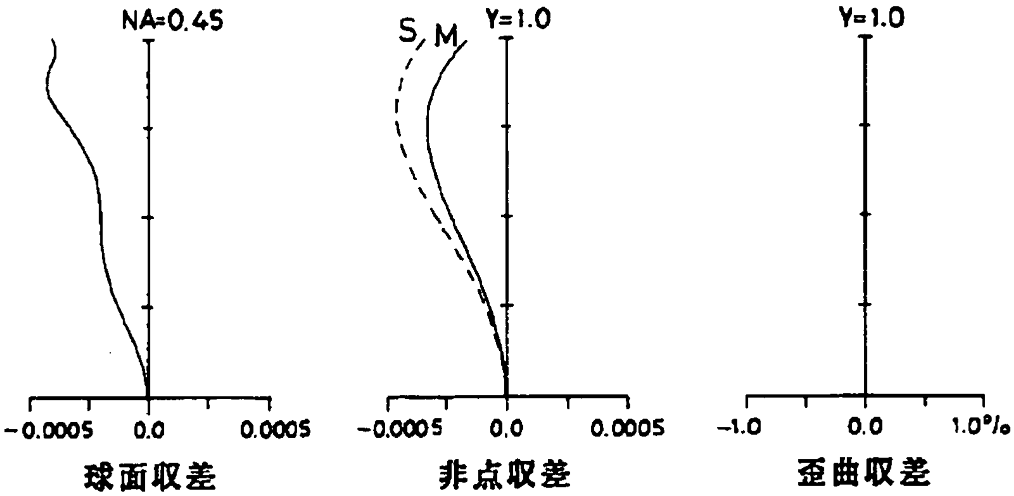
[Drawing 12]

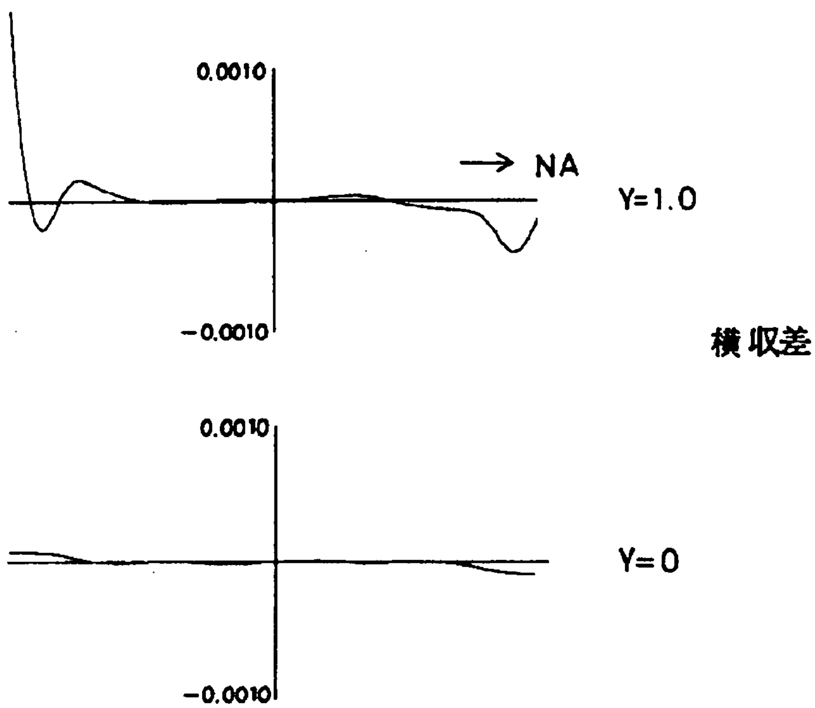

NA= 0.45
S
M
Y=1.0
Y=1.0
-0.001 -0.0005 0 0.0005 0.001
球面収差
-0.002 -0.001 0 0.001 0.002
非点収差
-1.0 -0.5 0 0.5 1.0%
歪曲収差
0.0025 mm
NA
Y=1.0
-0.0025
0.0025
Y=0.9
-0.0025
0.0025
Y=0.7
横収差
-0.0025
0.0025
Y=0.4
-0.0025
0.0025
Y=0
-0.0025

[Drawing 14]

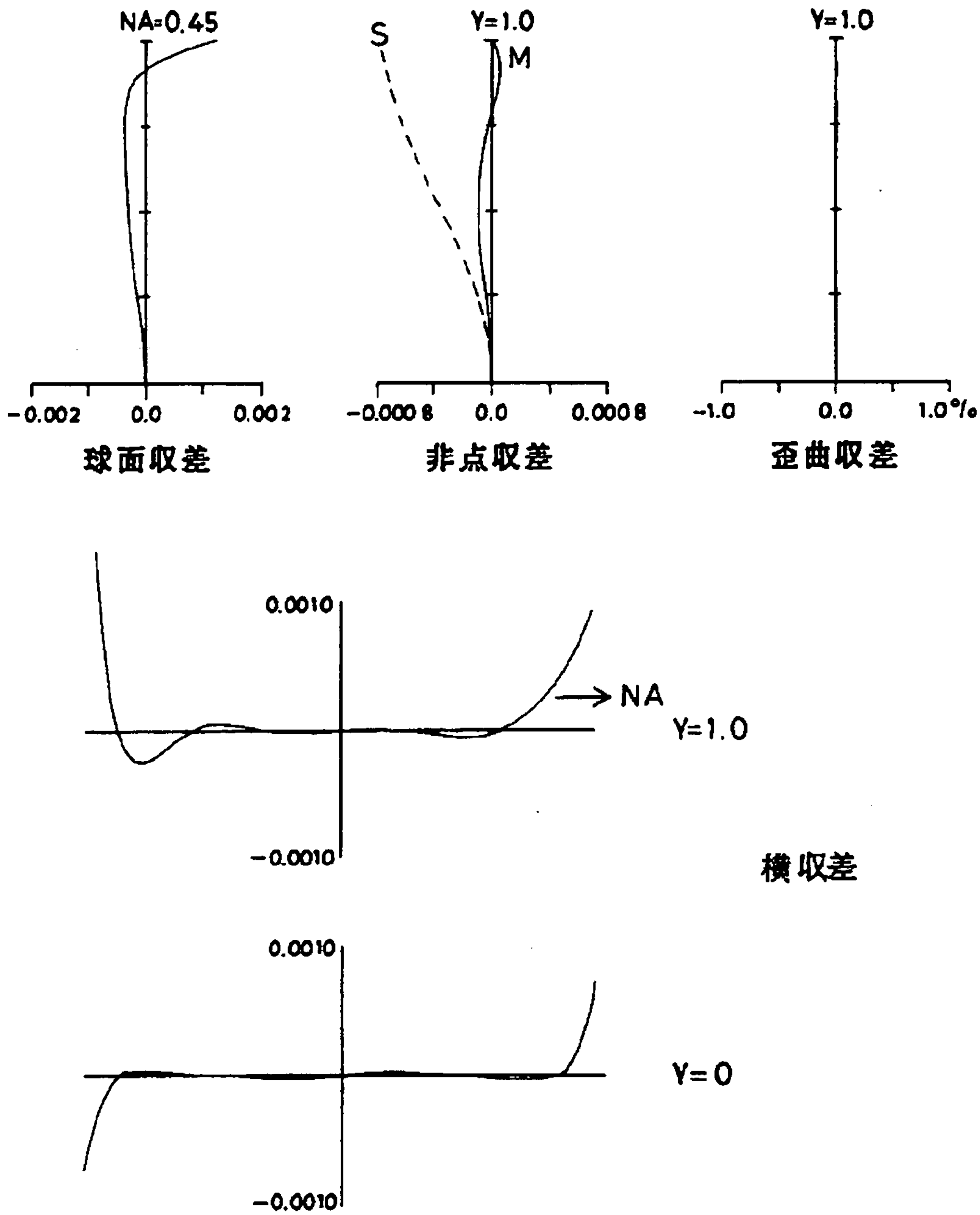

NA=0.45
S M Y=1.0
Y=1.0
-0.0005 0.0 0.0005
-0.0008 0.0 0.0008
-1.0 0.0 1.0%
球面収差
非点収差
歪曲収差
0.0010
NA
Y=1.0
-0.0010
横収差
0.0010
Y=0
-0.0010

[Drawing 15]

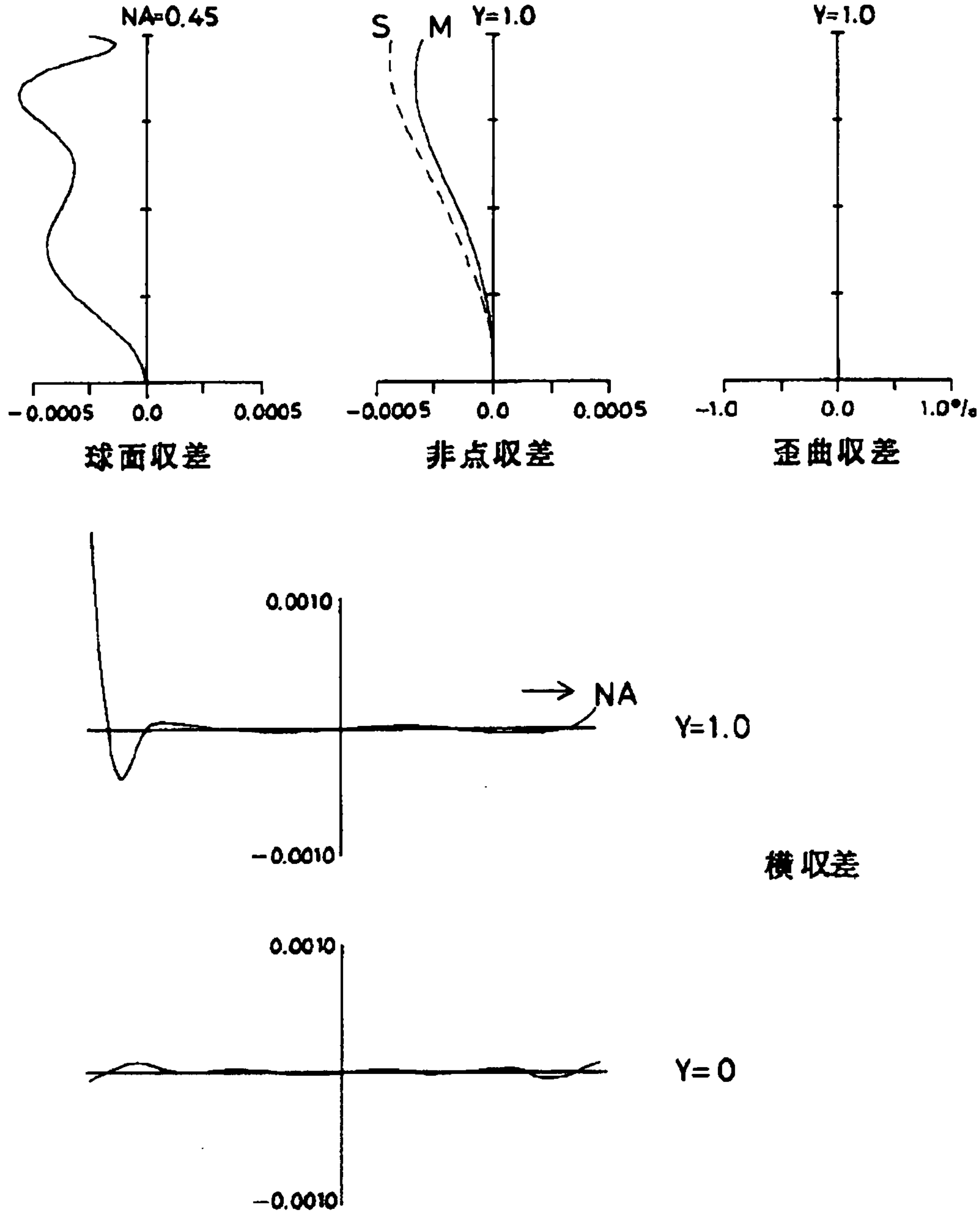

NA=0.45
S
M
Y=1.0
Y=1.0
-0.0005
0.0
0.0005
球面収差
-0.0005
0.0
0.0005
非点収差
-1.0
0.0
1.0%
歪曲収差


0.0010
→ NA
Y=1.0
-0.0010
横収差
0.0010
Y=0
-0.0010

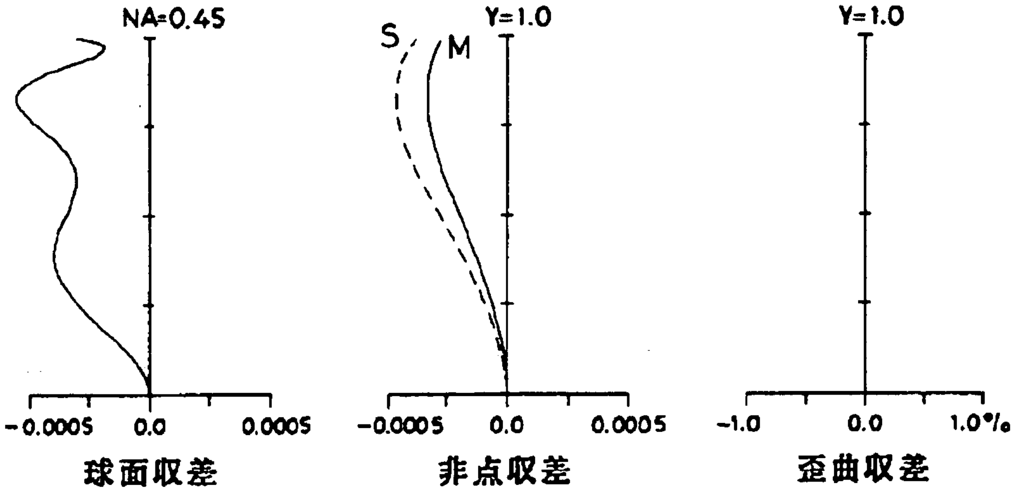
[Drawing 16]

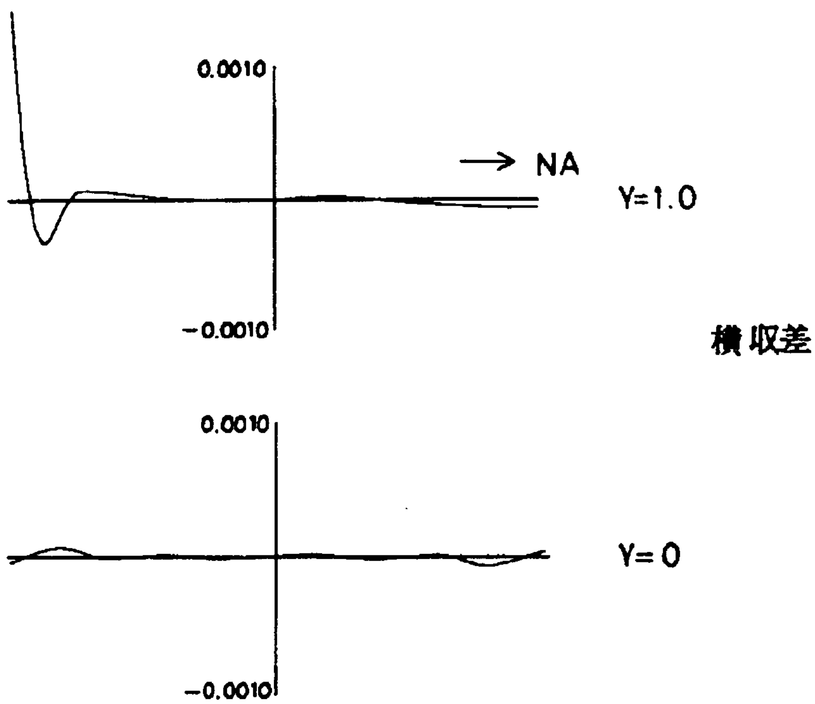

NA=0.45
-0.002
0.0
0.002
球面収差
S
Y=1.0
M
-0.0008
0.0
0.0008
非点収差
Y=1.0
-1.0
0.0
1.0%
歪曲収差
0.0010
-0.0010
NA
Y=1.0
横収差
0.0010
-0.0010
Y=0

[Drawing 17]


NA=0.45
S
M
Y=1.0
Y=1.0
-0.0005
0.0
0.0005
-0.0005
0.0
0.0005
-1.0
0.0
1.0%
球面収差
非点収差
歪曲収差
0.0010
NA
Y=1.0
-0.0010
横収差
0.0010
Y=0
-0.0010

[Drawing 18]





[Translation done.]

CORRECTION OR AMENDMENT

[Official Gazette Type] Printing of amendment by convention of 2 of Article 17 of patent law
[A section partition] The 2nd partition of the 6th section
[The date of issue] December 8, Heisei 10 (1998)

[Publication No.] Publication number 5-34593
[Date of Publication] February 12, Heisei 5 (1993)
[Year copy format] Open patent official report 5-346
[Filing Number] Japanese Patent Application No. 3-281223
[International Patent Classification (6th Edition)]

```
G02B  13/24
13/14
13/18
```

[FI]

```
G02B  13/24
13/14
13/18
```

[Procedure revision]
[Filing Date] June 17, Heisei 10
[Procedure amendment 1]
[Document to be Amended] Specification
[Item(s) to be Amended] Claim
[Method of Amendment] Modification
[Proposed Amendment]
[Claim(s)]
[Claim 1] It consists of positive 4th lens groups which have at least one meniscus lens which turned the positive 1st lens group, the negative 2nd lens group, and the positive 3rd lens group, and turned a concave surface to an image side in order [side / body],
an unit or two or more lenses which consist of a with a refractive index of 1.6 or less glass material constitute each lens group -- having -- and
A contraction projection lens characterized by arranging the page [1st / at least] aspheric surface at the 2nd lens group and the 4th lens group, respectively.
[Claim 2] A contraction projection lens according to claim 1 characterized by being constituted by both tele cent rucksack by which an entrance pupil and an exit pupil location were fully set up in the distance.
[Claim 3] SiO2 from -- a contraction projection lens which consists of two or more becoming lenses, and total thickness of a lens is 1/4 or less [of length between object images], and is characterized by being constituted by both-sides tele cent rucksack in order to form a body image by light with a wavelength of 250nm or less.
[Claim 4] It consists of positive 4th lens groups which have at least one meniscus lens which turned the positive 1st lens group, the negative 2nd lens group, and the positive 3rd lens group, and turned a concave surface to an image side in order [side / body],

The 1st lens group projects an entrance pupil in a method of abbreviation infinite distance of a RENSU system near the 3rd lens group,
The 2nd lens group has the aspheric surface,
the 3rd lens group -- emission light from the 2nd lens group -- abbreviation -- the parallel flux of light -- changing
The 4th lens group is a contraction projection lens system characterized by having the aspheric surface.
[Claim 5] A contraction projection lens system characterized by satisfying the following conditions in claim 1 or 4.
| f34|<D/5 ... **
However, f34 is the synthetic focal distance of the 3rd lens group and the 4th lens group, and D is length between object images.
[Claim 6] A contraction projection lens system characterized by satisfying the following conditions in claim 1 or 4.
f4 <D/2 ... **
However, f4 A focal distance of the 4th lens group and D are length between object images.
[Claim 7] In claim 1 or 4,
The 1st lens group consists of a biconvex lens,
The 2nd lens group consists of a biconcave lens,
A contraction projection lens system characterized by consisting of a pre-group which the 3rd lens group turns into from a biconvex lens, and a back group of two negative meniscus lenses which opposed a concave surface.
[Claim 8] In claim 7,
A contraction projection lens system characterized by the 4th lens group consisting of a biconvex lens and a positive meniscus lens which turned a concave surface to an image side.
[Claim 9] In claim 7,
A contraction projection lens system characterized by the 4th lens group consisting of two biconvex lenses and a negative meniscus lens which turned a concave surface to an image side.
[Claim 10] In claim 7,
A contraction projection lens system characterized by the 4th lens group consisting of a biconvex lens and two positive meniscus lenses which turned a concave surface to an image side.
[Claim 11] In claim 1 or 4,
The 1st lens group consists of a positive meniscus lens which turned a concave surface to a body side,
The 2nd lens group consists of a biconcave lens,
A contraction projection lens system characterized by the 3rd lens group consisting of a biconvex lens.
[Claim 12] In claim 11,
A contraction projection lens system characterized by consisting of a positive meniscus lens with which the 4th lens group turned a concave surface to an image side, and a negative meniscus lens which turned a concave surface to an image side.
[Claim 13] In claim 11,
A contraction projection lens system characterized by the 4th lens group consisting of a biconvex lens and a negative meniscus lens which turned a concave surface to an image side.
[Claim 14] A contraction projection lens system characterized by satisfying the following conditions in claims 8 and 9 or 10.
f1 <D/2.5 ... **
However, f1 A focal distance of the 1st lens group and D are length between object images.
[Claim 15] A contraction projection lens system characterized by thickness of two negative MENIME dregs lenses of the 3rd lens group being 1/4 or less [of an effective diameter] in claims 8 and 9 or 10.
[Claim 16] A contraction projection lens system characterized by satisfying the following conditions in claims 8 and 9 or 10.
| f2 |<D/5 ... **
However, f2 A focal distance of the 2nd lens group and D are length between object images.
[Claim 17] A contraction projection lens system characterized by satisfying the following conditions in claim 12 or 13.
D/3<f1 <D ... **
However, f1 A focal distance of the 1st lens group and D are length between object images.
[Claim 18] A contraction projection lens system characterized by satisfying the following conditions in claim 12 or 13.
D/10<|f2 | ... **
However, f2 A focal distance of the 2nd lens group and D are length between object images.
[Procedure amendment 2]

[Document to be Amended] Specification
[Item(s) to be Amended] 0009
[Method of Amendment] Modification
[Proposed Amendment]
[0009] another contraction projection lens of this invention -- SiO2 from -- it consists of two or more becoming lenses, the total thickness of a lens is 1/4 or less [of length between object images], and in order to form a body image by light with a wavelength of 250nm or less, it is characterized by being constituted by the both-sides tele cent rucksack. This invention further another contraction projection lens In order [side / body], the positive 1st lens group, the negative 2nd lens group, the positive 3rd lens group, It consists of positive 4th lens groups which have at least one meniscus lens which turned the concave surface to the image side. the entrance pupil which the 1st lens group has in the method of abbreviation infinite distance of a RENSU system -- the near 3rd lens group -- projecting -- the 2nd lens group -- the aspheric surface -- having -- the 3rd lens group -- the emission light from the 2nd lens group -- abbreviation -- it changes into the parallel flux of light, and the 4th lens group is characterized by having the aspheric surface.

[Translation done.]

(19)日本国特許庁（ＪＰ）　(12) 公開特許公報（Ａ）　(11)特許出願公開番号

特開平5－34593

(43)公開日　平成5年(1993)2月12日

(51)Int.Cl.5		識別記号	庁内整理番号	FI	技術表示箇所
G02B	13/24		8106－2K		
	13/14		8106－2K		
	13/18		8106－2K		

審査請求　未請求　請求項の数2（全 21 頁）

(21)出願番号　特願平3－281223

(22)出願日　平成3年(1991)10月28日

(31)優先権主張番号　特願平3－117307

(32)優先日　平3(1991)5月22日

(33)優先権主張国　日本（ＪＰ）

(71)出願人　000000376
オリンパス光学工業株式会社
東京都渋谷区幡ケ谷2丁目43番2号

(72)発明者　研野孝吉
東京都渋谷区幡ケ谷2丁目43番2号オリンパス光学工業株式会社内

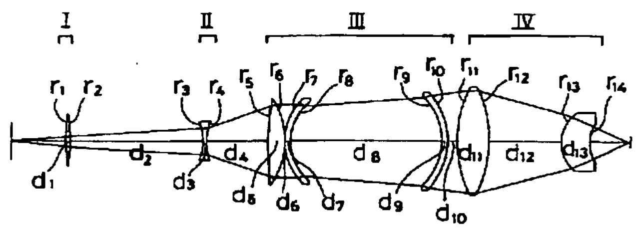
(74)代理人　弁理士　韮澤　弘　（外7名）

(54)【発明の名称】　縮小投影レンズ

(57)【要約】

【目的】　レンズ系硝材総肉厚が薄くて透過率が良く、広い露光領域と高い解像力を持った物体側、像側両テレセントリック縮小投影レンズ。

【構成】　正の第1レンズ群Ｉ、負の第2レンズ群II、正の第3レンズ群III、像側に凹面を向けたメニスカスレンズを少なくとも1枚有する正の第4レンズ群IVで構成され、各レンズ群は屈折率1．6以下のガラス材料からなる単数又は複数のレンズにより構成され、かつ、第2レンズ群II、第4レンズ群IVにそれぞれ少なくとも1面の非球面が配置されている。



【特許請求の範囲】
【請求項１】　物体側より順に、正の第１レンズ群、負の第２レンズ群、正の第３レンズ群、像側に凹面を向けたメニスカスレンズを少なくとも１枚有する正の第４レンズ群で構成され、各レンズ群は屈折率１．６以下のガラス材料からなる単数又は複数のレンズにより構成され、かつ、第２レンズ群、第４レンズ群にそれぞれ少なくとも１面の非球面が配置されていることを特徴とする縮小投影レンズ。
【請求項２】　入射瞳及び射出瞳位置が十分に遠くに設定された両テレセントリックに構成されていることを特徴とする請求項１記載の縮小投影レンズ。
【発明の詳細な説明】
【０００１】
【産業上の利用分野】本発明は、縮小投影レンズに関し、特に、縮小投影露光法によって回路パターンの描かれたマスク等から回路パターン等を転写する際に用いる縮小投影レンズに関するものである。
【０００２】
【従来の技術】一般に、投影レンズによる投影像の解像力はその開口数に比例し、使用する波長に反比例する。近年、回路パターンの高集積化が一段と進み、さらに解像力の良いレンズが要求されてきており、開口数を大きくして行くとそれに比例して解像力は良くなって行くが、焦点深度が浅くなり、焦点合わせを非常に正確に行う必要が生ずる。また、回路パターンを転写するシリコンウエハーの平坦度も非常に厳しい値が要求され、実用には向かなくなってしまう。
【０００３】そのため、近年では、開口数を大きくするよりも、使用波長を短くして焦点深度を保ちつつ解像力を上げることが行われるようになった。
【０００４】現在では、水銀灯による波長４３６ｎｍから３６５ｎｍの光が使用されるようになっているが、近年、２４８ｎｍを発光スペクトルとするＫｒＦエキシマレーザを使用する特開昭６０－１４０３１０号等の提案がある。
【０００５】
【発明が解決しようとする課題】ところで、使用波長が２５０ｎｍ以下になると、使用できる硝材は、透過率から、SiO_2 又は CaF_2 に限られ、しかも加工性等を考慮すると、SiO_2 しか使用できる硝材はない。さらに、２００ｎｍ以下では、この SiO_2 を使用しても、透過率が低いために、硝材総肉厚は、２００ｍｍ前後以下にしないと、透過率が５０％以下になってしまう。そこで、レンズ系の硝材総肉厚が少しでも短いことが必要条件になってくるが、上記した特開昭６０－１４０３１０号等のものにおいては、レンズ系の硝材総肉厚が２００ｍｍより厚いものである。また、回路パターンを転写するときのフォーカスエラーによって生ずる投影倍率の変化がないように、射出瞳位置が実質的に無限遠の像側テレセントリックな光学系にすることが知られている。しかし、解像力が高くなるに従って、この投影倍率の変化は、さらに厳しいものが要求されてきており、像側だけにとどまらず物体側のマスクの平坦度による倍率変化も起きないように、物体側テレセントリックな光学系が要求されている。
【０００６】本発明はこのような状況に鑑みてなされたものであり、その目的は、レンズ系硝材総肉厚を物像間距離の４分の１以下にして透過率を良くし、なおかつ、広い露光領域と高い解像力を持った物体側、像側両テレセントリック縮小投影レンズを提供することである。
【０００７】なお、本発明の投影レンズにおいては、１９３ｎｍを主な発光スペクトルとするＡｒＦエキシマレーザ等を用いるが、２４８ｎｍを主な発光スペクトルとするＫｒＦエキシマレーザにおいても使用できることは当然である。
【０００８】
【課題を解決するための手段】上記目的を達成するために、本発明の縮小投影レンズは、物体側より順に、正の第１レンズ群、負の第２レンズ群、正の第３レンズ群、像側に凹面を向けたメニスカスレンズを少なくとも１枚有する正の第４レンズ群で構成され、各レンズ群は屈折率１．６以下のガラス材料からなる単数又は複数のレンズにより構成され、かつ、第２レンズ群、第４レンズ群にそれぞれ少なくとも１面の非球面が配置されていることを特徴とするものである。
【０００９】この場合、入射瞳及び射出瞳位置が十分に遠くに設定された両テレセントリックに構成されるのが望ましい。
【００１０】
【作用】以下、上記のような構成を採用した理由と作用について説明する。高解像力と広い露光領域を確保するためには、像面湾曲をほぼ完全に補正しなければならないことは良く知られている。
【００１１】また、物体側、像側の両テレセントリック光学系では、レンズ系中央付近にある瞳を物体側、像側の双方で無限遠に投影する必要があり、物体近傍と像近傍に正のレンズ群を配し、レンズ系中央付近の瞳を無限遠方に結像させるようにしている。
【００１２】さらに、レンズ系総肉厚を薄くするためには、レンズ１枚１枚を薄くする必要があり、かつ、各々のレンズ群を構成するレンズエレメントの数を減らすことが重要である。
【００１３】上記３つの必要条件は、互いに矛盾する点が多い。例えば、像面湾曲を補正するためにペッツバール和をほとんんどゼロに補正するために、マージナル光線が比較的低い物体近傍か像近傍に負レンズを配す必要がある。
【００１４】以上のように、高解像力と広い露光領域を確保するために、両テレセントリック系レンズにするこ

ととレンズ系の総肉厚を薄くするという条件は、非常に難しい制限条件となる。

【００１５】本発明は、以上のように相互に矛盾する制限条件を満足するためになされたものであり、以下に各群の配置と作用に関して説明をする。

【００１６】テレセントリック光学系にするために、第１レンズ群と第４レンズ群に正のレンズ系を配している。

【００１７】第１レンズ群の正パワーは、無限遠の入射瞳をレンズ系中央にある強い正の屈折力を持つ第３レンズ群近傍に投影し、この第３レンズ群で発生するコマ収差を小さくするためのものである。

【００１８】第２レンズ群は、ペッツバール和の補正と光線高を高くするために強い負レンズとなっている。広い露光領域を確保するためには、像面湾曲のないレンズ系にする必要があり、そのためには、ペッツバール和を小さくすることが一般によく知られている。また、強い負のレンズ系を用いると、強い負の球面収差が発生し、他の群で発生する正の球面収差とバランスさせることができなくなる。そこで、第２レンズ群に非球面を使うことで、さらに良好な球面収差に補正することができる。

【００１９】第３レンズ群は、第２レンズ群の負の屈折力を強くさせる働きがある。第３レンズ群は、第２レンズ群で発散光束となってしまった物体からの光束を概略平行光束にするために、正の屈折力を有する必要があり、第３レンズ群の正の屈折力が弱いと、第２レンズ群の負の屈折力も弱くなり、上記ペッツバール和が良好に補正できない。

【００２０】第４レンズ群は、両テレセントリック光学系で、全系の物像間距離Ｄと倍率βを決める群となる。この強い正の屈折力のため、レンズ系の構成要素が少ない本発明の場合は、球面レンズ系では必ず正の球面収差が発生してしまう。そこで、本発明では、この第４レンズ群にも非球面を少なくとも１面使用することにより、第４レンズ群で発生する球面収差を良好に補正している。もし、非球面を用いない場合には、第４レンズ群で発生する球面収差を補正しようとしても、本発明のようにレンズエレメントの数が少ないレンズ系においては、他の群で補正することが不可能である。

【００２１】また、第３レンズ群と第４レンズ群の合成焦点距離をf_{34}とし、物像間距離をＤとし、

$$|f_{34}| < D/5 \quad \cdots ①$$

の条件を満足するようにすると、レンズ系全長を小さくすることができる。この条件①の範囲を越えると、物像間距離Ｄが実用になる距離を遙かに越え、このレンズ系を用いる縮小投影露光装置が非常に大型となり、実用に耐えなくなる。

【００２２】また、第４レンズ群は、両テレセントリック光学系において全系の物像間距離Ｄと倍率βを決める群となるので、この群の焦点距離をf_4とすると、

$$f_4 < D/2 \quad \cdots ②$$

なる条件を満足する必要がある。

【００２３】

【実施例】以下、この発明の実施例を示す。実施例１～３のレンズ系の断面図をそれぞれ図１～図３に示す。何れの実施例においても、第１群Ｉは両凸正レンズ１枚から、第２群IIは両凹負レンズ１枚から、第３群III は両凸正レンズ１枚の前群と凹面が向き合った２枚の負メニスカスレンズの後群とからなる。第４群IVは、実施例１においては、両凸正レンズと像側に凹面を向けた正メニスカスレンズの２枚からなり、実施例２においては、両凸正レンズ２枚と像側に凹面を向けた負メニスカスレンズの３枚からなり、実施例３においては、両凸正レンズと像側に凹面を向けた正メニスカスレンズの２枚からなる。

【００２４】実施例４～９のレンズ系の断面図をそれぞれ図４～９に示す。何れの実施例においても、第１群Ｉは物体側に凹面を向けた正メニスカスレンズ１枚から、第２群IIは、両凹負レンズ１枚から、第３群III は両凸正レンズ１枚からなる。第４群IVは、実施例４、７においては、像側に凹面を向けた正メニスカスレンズと像側に凹面を向けた負メニスカスレンズの２枚からなり、実施例５、６、８、９においては、両凸正レンズと像側に凹面を向けた負メニスカスレンズの２枚からなる。

【００２５】非球面については、実施例１においては、第１レンズ群、第２レンス群それぞれの第１面、第３レンズ群の第１面と第４面、第４レンズ群の第１面と最終面の６面に用いており、実施例２においては、第１レンズ群、第２レンズ群それぞれの第１面、第３レンズ群の第４面、第４レンズ群の第１面と最終面の第５面に用いており、また、実施例３においては、第１レンズ群、第２レンズ群それぞれの第１面、第３レンズ群の第１面と第４面と第６面、第４レンズ群の第１面と最終面の７面に用いている。

【００２６】実施例４～９においては、実施例４では、第２レンズ群の第２面、第３レンズ群の第１面、第４レンズ群の最終面の３面に用いており、実施例５では、第１レンズ群、第２レンズ群、第３レンズ群それぞれの第１面、第４レンズ群の第１面と最終面の５面に用いており、実施例６では、第２レンズ群、第３レンズ群それぞれの第１面、第４レンズ群の第１面と最終面の４面に用いており、実施例７では、第１レンズ群、第２レンズ群、第３レンズ群それぞれの第１面、第４レンズ群の最終面の４面に用いており、実施例８では、第１レンズ群の第１面、第２レンズ群の第２面、第３レンズ群の第１面、第４レンズ群の第１面と最終面の５面に用いており、実施例９では、第２レンズ群の第２面、第３レンズ

群の第１面、第４レンズ群の第１面と最終面の４面に用いている。

【００２７】本発明において、ペッツバール和の補正とコマ収差の補正が収差補正上重要な位置を占めることは、上記した通りである。そこで、実施例１～３と実施例４～９の違いについて説明する。

【００２８】ペッツバール和を小さくするためには、レンズ系の中の負の屈折力を持った凹面を多くするか、又は、その屈折力を強くすることが重要である。実施例１～３の場合は、これを、凹面向かい合わせたガウスタイプを使うことによって、負の屈折力を持つ面を増やして

f_1＜Ｄ／２．５

なる条件を満足することが重要である。この上限を越えると、第３レンズ群III後群の向き合った凹面でのコマ収差補正能力が低くなってしまうからである。この向き合った凹面で構成されたメニスカスレンズは、この後群を通過する光線の上側光束と下側光束の対称性から、コマフレアーの補正を行うのに有効である。なお、このメニスカスレンズの中心肉厚は、全系の透過率の問題から、有効径の１／４以下とするのが好ましい。さらに、

Ｄ／３＜f_1＜Ｄ

なる条件の範囲にすると、第３レンズ群III 近傍に入射瞳が投影され、第３レンズ群III で発生するコマ収差が少なくなり、より広い露光領域を確保することができる。この条件④から外れると、第３レンズ群III で発生するコマ収差が大きくなり、コマ収差の補正のために他のレンズエレメントの数が多くなり、レンズ系の総肉厚

｜f_2｜＜Ｄ／５

なる条件を満足することが重要である。この条件⑤の上限を越えて、負の焦点距離が延びてしまうと、ペッツバール和の補正ができなくなってしまう。なお、このペッツバール和の補正のために、第３レンズ群III 後群の負の屈折力を強くしてしまうと、第３レンズ群III 後群で補正しているコマ収差とコマフレアーの発生が大きくな

Ｄ／１０＜｜f_2｜

なる条件を満足することが重要である。この条件式⑥は、レンズ系全体を通して負のレンズ群はこの第２レンズ群IIのみとなる実施例４～９において、負レンズの焦点距離を短くすると、ペッツバール和の補正に効果があり、フラットな像面を得るには好都合である。しかし、上記条件⑥の下限を越えて、第２レンズ群IIの焦点距離が短くなると、負レンズの屈折力が強くなりすぎ、コマ収差等に悪影響を与える。そこで、実施例４～９の場合は、向き合った凹面がない代わりに、第２レンズ群IIと第３レンズ群III の間隔を短くし、第３レンズ群III 近傍に瞳位置を置いて、第２レンズ群IIでの軸外主光線の光線高を低く抑えることに成功したため、第２レンズ群

解決している。実施例４～９では、第２レンズ群IIから所定量距離をおいて正の屈折力を持つ第３レンズ群IIIを配置することで、第２レンズ群IIの負の屈折力を強くして、ペッツバール和を補正している。

【００２９】なお、コマ収差については、第３レンズ群III にコマ収差の補正能力を積極的に持たせたガウスタイプを採用したのが実施例１～３であり、実施例４～９では第３レンズ群III で発生するコマ収差をなるべく小さくして、他のレンズ群によって補正している。

【００３０】さらに、好ましくは、実施例１～３では、第１レンズ群Ｉの焦点距離 f_1 は、

・・・③

瞳位置をはさんで凹面が向き合っているために、歪曲収差と非点収差を発生させないことが良く知られている。また、この向き合った凹面で構成されたメニスカスレンズの各面の働きを十分に引き出すためには、これらメニスカスレンズを通過する光線高を高くすることが必要である。

【００３１】一方、実施例４～９では、第１レンズ群Ｉの焦点距離を f_1 とすると、

・・・④

が厚くなってしまう。

【００３２】また、第２レンズ群IIは、ペッツバール和の補正のため、強い負レンズとなっている。実施例１～３では、さらに好ましくは、第２レンズ群IIの焦点距離を f_2 とし、

・・・⑤

って、広い露光領域が確保できなくなる。

【００３３】一方、実施例４～９では、向き合った凹面で構成する第３レンズ群III 後群がないために、第２レンズ群IIでコマ収差の発生が多くなりすぎると、他の群で補正することが困難になる。そこで、第２レンズ群IIの焦点距離を f_2 とし、

・・・⑥

IIで発生するコマ収差が少なくなっている。

【００３４】次に、これら実施例のレンズデータを示すが、硝材は全て溶融石英SiO_2からなる。記号は、f_1、f_2、f_3、f_4 はそれぞれ第１レンズ群ないし第４レンズ群の焦点距離、f_{34}は第３レンズ群と第４レンズ群の合成焦点距離、r_1、r_2…は各レンズ面の曲率半径、d_1、d_2…は各レンズ面間の間隔、n_{1931}、n_{1932}…は各レンズの１９３ｎｍでの屈折率、ν_1、ν_2…は各レンズのアッベ数であり、また、非球面形状は、光軸方向をｘ、光軸に直交する方向をｙとした時、次の式で表される。

【００３５】

$$x=(y^2/r)\,/\,[1+\{1-P(y^2/r^2)\}^{1/2}]+A_4y^4+A_6y^6+A_8y^8+A_{10}y^{10}$$

ただし、ｒは近軸曲率半径、Ｐは円錐係数、A_4、A_6、A_8、A_{10} は非球面係数である。

【００３６】なお、各実施例の倍率は１／５、開口数ＮＡは０．４５、物像間距離Ｄは１０００mm、露光領域は、実施例１、２、４～９においては１０×１０mm、実施例３においては１５×１５mmである。また、焦点距離については、本発明の投影レンズは物体側、像側に両テレセントリックなレンズ系であるので、何れの実施例も無限大である。

【００３７】実施例１

r_1 = 451.692（非球面）	d_1 = 6.713	n_{1931} =1.56 (SiO_2)	ν_1=67.8
r_2 = -288.953	d_2 = 217.576		
r_3 = -91.166（非球面）	d_3 = 5.000	n_{1932} =1.56 (SiO_2)	ν_2=67.8
r_4 = 91.869	d_4 = 101.863		
r_5 = 735.532（非球面）	d_5 = 26.997	n_{1933} =1.56 (SiO_2)	ν_3=67.8
r_6 = -136.072	d_6 = 0.339		
r_7 = 108.940	d_7 = 8.578	n_{1934} =1.56 (SiO_2)	ν_4=67.8
r_8 = 97.643（非球面）	d_8 = 245.090		
r_9 = -118.470	d_9 = 9.457	n_{1935} =1.56 (SiO_2)	ν_5=67.8
r_{10}= -139.413	d_{10}= 14.230		
r_{11}= 248.505（非球面）	d_{11}= 49.436	n_{1936} =1.56 (SiO_2)	ν_6=67.8
r_{12}= -228.156	d_{12}= 114.603		
r_{13}= 67.874	d_{13}= 44.827	n_{1937} =1.56 (SiO_2)	ν_7=67.8
r_{14}= 75.136（非球面）			

非球面係数

第１面

Ｐ ＝ 1

A_4 ＝ 2.93249×10^{-8}

A_6 ＝-6.01561×10^{-13}

A_8 ＝ 7.75262×10^{-17}

A_{10} ＝-1.59422×10^{-20}

第３面

Ｐ ＝ 1

A_4 ＝ 1.70739×10^{-7}

A_6 ＝-9.00445×10^{-12}

A_8 ＝-1.88095×10^{-16}

A_{10} ＝ 3.32351×10^{-18}

第５面

Ｐ ＝ 1

A_4 ＝ 3.77679×10^{-9}

A_6 ＝ 1.18388×10^{-13}

A_8 ＝-6.91515×10^{-17}

A_{10} ＝ 1.78302×10^{-21}

第８面

Ｐ ＝ 1

A_4 ＝ 2.24951×10^{-8}

A_6 ＝ 5.83034×10^{-13}

A_8 ＝ 1.81963×10^{-17}

A_{10} ＝ 3.58875×10^{-21}

第１１面

Ｐ ＝ 1

A_4 ＝-2.18203×10^{-8}

A_6 ＝-5.58764×10^{-13}

A_8 ＝-3.39369×10^{-18}

A_{10} ＝ 4.26460×10^{-22}

第１４面

Ｐ ＝ 1

A_4 ＝ 4.78744×10^{-7}

A_6 ＝ 9.95229×10^{-11}

A_8 ＝ 1.82581×10^{-14}

A_{10} ＝ 9.52854×10^{-18}

f_1 ＝ 315.709

f_2 ＝ -80.917

f_3 ＝ 219.905

f_4 ＝ 152.611

f_{34}＝ 608.503

【００３８】実施例２

r_1 = 346.678（非球面）	d_1 = 8.996	n_{193} =1.56 (SiO_2)	ν =67.8
r_2 = -211.745	d_2 = 116.945		
r_3 = -84.931（非球面）	d_3 = 5.000	n_{193} =1.56 (SiO_2)	ν =67.8
r_4 = 92.254	d_4 = 73.419		
r_5 = 690.064	d_5 = 18.505	n_{193} =1.56 (SiO_2)	ν =67.8
r_6 = -118.105	d_6 = 221.548		
r_7 = 110.508	d_7 = 6.107	n_{193} =1.56 (SiO_2)	ν =67.8
r_8 = 94.010（非球面）	d_8 = 215.600		

r_9 = −116.782	d_9 = 5.000	n_{193} =1.56 (SiO_2)	ν =67.8
r_{10}= −135.508	d_{10}= 0.100		
r_{11}= 254.527 (非球面)	d_{11}= 12.600	n_{193} =1.56 (SiO_2)	ν =67.8
r_{12}=−7731.132	d_{12}= 0.100		
r_{13}= 321.598	d_{13}= 38.382	n_{193} =1.56 (SiO_2)	ν =67.8
r_{14}= −249.389	d_{14}= 97.319		
r_{15}= 54.043	d_{15}= 46.683	n_{193} =1.56 (SiO_2)	ν =67.8
r_{16}= 45.969 (非球面)			

非球面係数

第１面

P　＝ 1

A_4 ＝ 3.50944×10^{-8}

A_6 ＝-1.17311×10^{-12}

A_8 ＝-9.39000×10^{-17}

A_{10} ＝-1.18581×10^{-20}

第３面

P　＝ 1

A_4 ＝ 1.51045×10^{-7}

A_6 ＝ 3.15495×10^{-11}

A_8 ＝ 7.17742×10^{-15}

A_{10} ＝ 1.17334×10^{-18}

第８面

P　＝ 1

A_4 ＝ 2.41442×10^{-8}

A_6 ＝-1.37501×10^{-13}

A_8 ＝-3.82684×10^{-17}

A_{10} ＝-4.07941×10^{-21}

第１１面

P　＝ 1

A_4 ＝-2.85336×10^{-8}

A_6 ＝-9.27780×10^{-13}

A_8 ＝-9.61658×10^{-18}

A_{10} ＝ 5.57595×10^{-22}

第１６面

P　＝ 1

A_4 ＝ 1.69376×10^{-6}

A_6 ＝ 1.04389×10^{-9}

A_8 ＝ 4.87186×10^{-13}

A_{10} ＝ 7.55304×10^{-16}

f_1 ＝ 236.105

f_2 ＝ −78.173

f_3 ＝ 150.720

f_4 ＝ 114.477

f_{34}＝−147.329

【００３９】実施例３

r_1 = 226.862 (非球面)	d_1 = 21.097	n_{193} =1.56 (SiO_2)	ν =67.8
r_2 = −331.243	d_2 = 156.694		
r_3 = −74.083 (非球面)	d_3 = 84.138	n_{193} =1.56 (SiO_2)	ν =67.8
r_4 = 84.138	d_4 = 104.086		
r_5 = 652.171 (非球面)	d_5 = 28.328	n_{193} =1.56 (SiO_2)	ν =67.8
r_6 = −137.525	d_6 = 20.895		
r_7 = 117.445	d_7 = 5.000	n_{193} =1.56 (SiO_2)	ν =67.8
r_8 = 103.697 (非球面)	d_8 = 236.472		
r_9 = −128.167	d_9 = 6.469	n_{193} =1.56 (SiO_2)	ν =67.8
r_{10}= −154.631 (非球面)	d_{10}= 6.469		
r_{11}= 190.291 (非球面)	d_{11}= 22.633	n_{193} =1.56 (SiO_2)	ν =67.8
r_{12}= −308.181	d_{12}= 117.017		
r_{13}= 68.215	d_{13}= 49.275	n_{193} =1.56 (SiO_2)	ν =67.8
r_{14}= 87.724 (非球面)			

非球面係数

第１面

P　＝ 1

A_4 ＝ 1.01346×10^{-8}

A_6 ＝-6.39640×10^{-13}

A_8 ＝-1.03771×10^{-17}

A_{10} ＝-3.19138×10^{-22}

第３面

P　＝ 1

A_4 ＝ 3.88528×10^{-7}

A_6 ＝ 3.09256×10^{-11}

A_8 ＝ 3.92110×10^{-15}

A_{10} ＝ 2.74269×10^{-18}

第５面

P　＝ 1

A_4 ＝ 4.35316×10^{-9}

A_6 $=-9.04323\times10^{-13}$
A_8 $=9.26304\times10^{-17}$
A_{10} $=-6.78193\times10^{-21}$
第８面
Ｐ ＝１
A_4 $=1.82229\times10^{-8}$
A_6 $=-2.70904\times10^{-13}$
A_8 $=1.92104\times10^{-17}$
A_{10} $=7.81170\times10^{-21}$
第１０面
Ｐ ＝１
A_4 $=-9.39398\times10^{-10}$
A_6 $=-7.71154\times10^{-14}$
A_8 $=-2.42008\times10^{-18}$
A_{10} $=-1.25911\times10^{-21}$
第１１面
Ｐ ＝１
A_4 $=-2.21247\times10^{-8}$
A_6 $=-6.04358\times10^{-13}$
A_8 $=-1.70217\times10^{-17}$
A_{10} $=3.49063\times10^{-22}$
第１４面
Ｐ ＝１
A_4 $=6.77267\times10^{-7}$
A_6 $=1.17636\times10^{-10}$
A_8 $=2.34623\times10^{-14}$
A_{10} $=1.16254\times10^{-17}$
$f_1=243.746$
$f_2=-59.072$
$f_3=220.394$
$f_4=162.576$
$f_{34}=671.921$

【００４０】実施例４

$r_1=-572.0476$	$d_1=10.000$	$n_{1931}=1.56\ (SiO_2)$	$\nu_1=67.8$
$r_2=-184.8433$	$d_2=409.771$		
$r_3=-458.4715$	$d_3=10.000$	$n_{1932}=1.56\ (SiO_2)$	$\nu_2=67.8$
$r_4=202.4878$ (非球面)	$d_4=190.139$		
$r_5=286.1623$ (非球面)	$d_5=45.952$	$n_{1933}=1.56\ (SiO_2)$	$\nu_3=67.8$
$r_6=-214.2468$	$d_6=45.952$		
$r_7=187.2298$	$d_7=29.313$	$n_{1934}=1.56\ (SiO_2)$	$\nu_4=67.8$
$r_8=2521.0651$	$d_8=97.435$		
$r_9=69.7454$	$d_9=44.735$	$n_{1935}=1.56\ (SiO_2)$	$\nu_5=67.8$
$r_{10}=42.0656$ (非球面)			

非球面係数
第４面
Ｐ ＝１
A_4 $=1.59538\times10^{-7}$
A_6 $=8.3103\times10^{-12}$
A_8 $=5.1193\times10^{-16}$
A_{10} $=-3.9590\times10^{-20}$
第５面
Ｐ ＝１
A_4 $=-3.72611\times10^{-8}$
A_6 $=6.90136\times10^{-14}$
A_8 $=7.79908\times10^{-18}$
A_{10} $=-1.74025\times10^{-22}$
第１０面
Ｐ ＝１
A_4 $=9.15018\times10^{-7}$
A_6 $=6.01403\times10^{-10}$
A_8 $=1.35777\times10^{-13}$
A_{10} $=5.31287\times10^{-16}$
$f_1=483.16993$
$f_2=-249.45725$
$f_3=226.24081$
$f_4=425.39731$
$f_{34}=105.47071$

【００４１】実施例５

$r_1=-541.2251$ (非球面)	$d_1=10.000$	$n_{1931}=1.56\ (SiO_2)$	$\nu_1=67.8$
$r_2=-178.508$	$d_2=380.563$		
$r_3=-116.7046$ (非球面)	$d_3=10.000$	$n_{1932}=1.56\ (SiO_2)$	$\nu_2=67.8$
$r_4=167.246$	$d_4=88.289$		
$r_5=493.1745$ (非球面)	$d_5=31.836$	$n_{1933}=1.56\ (SiO_2)$	$\nu_3=67.8$
$r_6=-167.779$	$d_6=152.364$		
$r_7=171.5560$ (非球面)	$d_7=39.607$	$n_{1934}=1.56\ (SiO_2)$	$\nu_4=67.8$
$r_8=-486.272$	$d_8=114.281$		
$r_9=62.349$	$d_9=48.557$	$n_{1935}=1.56\ (SiO_2)$	$\nu_5=67.8$

r_{10}= 47.5491 (非球面)

非球面係数

第１面

P = 1

A_4 = 2.03175×10^{-8}

A_6 = 3.10104×10^{-13}

A_8 = 3.35603×10^{-17}

A_{10} =−1.06665×10^{-20}

第３面

P = 1

A_4 =−8.73843×10^{-8}

A_6 = 2.43775×10^{-12}

A_8 = 3.77550×10^{-16}

A_{10} = 1.31565×10^{-19}

第５面

P = 1

A_4 =−1.65516×10^{-8}

A_6 =−4.46539×10^{-13}

A_8 = 3.83871×10^{-17}

A_{10} =−1.09113×10^{-21}

第７面

P = 1

A_4 =−2.77045×10^{-8}

A_6 =−6.49105×10^{-13}

A_8 =−1.28276×10^{-17}

A_{10} =−3.27926×10^{-22}

第１０面

P = 1

A_4 = 1.06582×10^{-6}

A_6 = 5.51608×10^{-10}

A_8 = 2.17457×10^{-13}

A_{10} = 2.85959×10^{-16}

f_1 = 470.98184

f_2 =−121.21548

f_3 = 227.48599

f_4 = 163.54116

f_{34}= 134.92856

【００４２】実施例６

r_1 = −639.5688	d_1 = 10.000	n_{1931} =1.56 (SiO_2)	ν_1=67.8
r_2 = −172.8565	d_2 = 336.346		
r_3 = −117.7121 (非球面)	d_3 = 10.000	n_{1932} =1.56 (SiO_2)	ν_2=67.8
r_4 = 138.9428	d_4 = 86.675		
r_5 = 428.5867 (非球面)	d_5 = 28.263	n_{1933} =1.56 (SiO_2)	ν_3=67.8
r_6 = −173.7725	d_6 = 167.149		
r_7 = 160.0200 (非球面)	d_7 = 35.5094	n_{1934} =1.56 (SiO_2)	ν_4=67.8
r_8 = −583.8214	d_8 = 101.926		
r_9 = 65.1302	d_9 = 56.228	n_{1935} =1.56 (SiO_2)	ν_5=67.8
r_{10}= 50.5856 (非球面)			

非球面係数

第３面

P = 1

A_4 =−4.97515×10^{-8}

A_6 = 1.00710×10^{-11}

A_8 = 5.58840×10^{-16}

A_{10} = 2.85451×10^{-19}

第５面

P = 1

A_4 =−9.69048×10^{-9}

A_6 =−7.78872×10^{-13}

A_8 = 5.68133×10^{-17}

A_{10} =−1.88990×10^{-21}

第７面

P = 1

A_4 =−3.18894×10^{-8}

A_6 =−7.74915×10^{-13}

A_8 =−2.05000×10^{-17}

A_{10} =−7.26451×10^{-22}

第１０面

P = 1

A_4 = 1.18566×10^{-6}

A_6 = 5.38757×10^{-10}

A_8 = 2.21170×10^{-13}

A_{10} = 1.78106×10^{-16}

f_1 = 419.75575

f_2 =−112.22444

f_3 = 224.57070

f_4 = 151.85925

f_{34}= 140.86807

【００４３】実施例７

r_1 = −177.6669 (非球面)	d_1 = 10.000	n_{1931} =1.56 (SiO_2)	ν_1=67.8
r_2 = −114.2492	d_2 = 419.764		

r_3 = -340.0667 (非球面)	d_3 = 10.000	n_{1932} =1.56 (SiO_2)	ν_2=67.8
r_4 = 147.5802	d_4 = 94.540		
r_5 = 316.7103 (非球面)	d_5 = 36.042	n_{1933} =1.56 (SiO_2)	ν_3=67.8
r_6 = -150.7398	d_6 = 229.790		
r_7 = 142.6463	d_7 = 19.393	n_{1934} =1.56 (SiO_2)	ν_4=67.8
r_8 = 2500.1875	d_8 = 32.167		
r_9 = 60.8011	d_9 = 64.565	n_{1935} =1.56 (SiO_2)	ν_5=67.8
r_{10}= 38.4152 (非球面)			

非球面係数

第１面

Ｐ　＝１

A_4 ＝ 2.96198×10^{-8}

A_6 ＝ 2.80539×10^{-12}

A_8 ＝ 3.32053×10^{-16}

A_{10} ＝ -3.12952×10^{-20}

第３面

Ｐ　＝１

A_4 ＝ -1.53160×10^{-7}

A_6 ＝ -7.02996×10^{-12}

A_8 ＝ -6.64599×10^{-16}

A_{10} ＝ -2.96550×10^{-20}

第５面

Ｐ　＝１

A_4 ＝ -3.63247×10^{-8}

A_6 ＝ -3.24021×10^{-13}

A_8 ＝ 2.73201×10^{-17}

A_{10} ＝ -5.07985×10^{-22}

第１０面

Ｐ　＝１

A_4 ＝ 2.72286×10^{-6}

A_6 ＝ 2.66106×10^{-9}

A_8 ＝ 1.32154×10^{-12}

A_{10} ＝ 6.12735×10^{-15}

f_1 ＝ 540.93912

f_2 ＝ -182.43733

f_3 ＝ 187.56708

f_4 ＝ 163.65149

f_{34}＝ 144.89599

【００４４】実施例８

r_1 = -770.5823 (非球面)	d_1 = 10.000	n_{1931} =1.56 (SiO_2)	ν_1=67.8
r_2 = -181.1563	d_2 = 323.852		
r_3 = -104.2579	d_3 = 10.000	n_{1932} =1.56 (SiO_2)	ν_2=67.8
r_4 = 152.4160 (非球面)	d_4 = 83.320		
r_5 = 687.3939 (非球面)	d_5 = 27.073	n_{1933} =1.56 (SiO_2)	ν_3=67.8
r_6 = -152.2819	d_6 = 199.438		
r_7 = 165.5278 (非球面)	d_7 = 37.254	n_{1934} =1.56 (SiO_2)	ν_4=67.8
r_8 = -521.4727	d_8 = 110.829		
r_9 = 64.7358	d_9 = 55.673	n_{1935} =1.56 (SiO_2)	ν_5=67.8
r_{10}= 51.6125 (非球面)			

非球面係数

第１面

Ｐ　＝１

A_4 ＝ 1.33179×10^{-8}

A_6 ＝ 1.51140×10^{-13}

A_8 ＝ -4.98385×10^{-17}

A_{10} ＝ 7.93760×10^{-21}

第４面

Ｐ　＝１

A_4 ＝ 2.63093×10^{-8}

A_6 ＝ -8.62168×10^{-12}

A_8 ＝ -5.04964×10^{-16}

A_{10} ＝ 5.54964×10^{-20}

第５面

Ｐ　＝１

A_4 ＝ -1.75977×10^{-8}

A_6 ＝ -2.26585×10^{-14}

A_8 ＝ 7.86457×10^{-18}

A_{10} ＝ -2.01203×10^{-22}

第７面

Ｐ　＝１

A_4 ＝ -2.71075×10^{-8}

A_6 ＝ -6.98608×10^{-13}

A_8 ＝ -1.54543×10^{-17}

A_{10} ＝ -4.67852×10^{-22}

第１０面

Ｐ　＝１

A_4 ＝ 1.20203×10^{-6}

A_6 ＝ 5. 58619×10^{-10}
A_8 ＝ 1. 88633×10^{-13}
A_{10} ＝ 2. 53098×10^{-16}
f_1 ＝ 420. 35709
f_2 ＝-109. 02802
f_3 ＝ 225. 22159
f_4 ＝ 152. 37870
f_{34}＝ 167. 04208 。

【００４５】実施例９

r_1 = -689. 8204	d_1 = 10. 000	n_{1931} =1. 56 (SiO_2)	ν_1=67. 8
r_2 = -175. 7935	d_2 = 335. 963		
r_3 = -117. 2918	d_3 = 10. 000	n_{1932} =1. 56 (SiO_2)	ν_2=67. 8
r_4 = 133. 7268 (非球面)	d_4 = 85. 589		
r_5 = 489. 8047 (非球面)	d_5 = 28. 595	n_{1933} =1. 56 (SiO_2)	ν_3=67. 8
r_6 = -164. 6619	d_6 = 165. 824		
r_7 = 164. 5730 (非球面)	d_7 = 36. 401	n_{1934} =1. 56 (SiO_2)	ν_4=67. 8
r_8 = -519. 6006	d_8 = 102. 620		
r_9 = 65. 0957	d_9 = 55. 004	n_{1935} =1. 56 (SiO_2)	ν_5=67. 8
r_{10}= 51. 1461 (非球面)			

非球面係数
第４面
Ｐ ＝ 1
A_4 ＝ 4. 70544×10^{-8}
A_6 ＝-9. 70520×10^{-12}
A_8 ＝-7. 80392×10^{-16}
A_{10} ＝ 5. 09643×10^{-20}
第５面
Ｐ ＝ 1
A_4 ＝-1. 03988×10^{-8}
A_6 ＝-2. 91909×10^{-13}
A_8 ＝ 8. 42545×10^{-18}
A_{10} ＝-3. 31289×10^{-23}
第７面
Ｐ ＝ 1
A_4 ＝-2. 93977×10^{-8}
A_6 ＝-7. 99535×10^{-13}
A_8 ＝-1. 74429×10^{-17}
A_{10} ＝-4. 57788×10^{-22}
第１０面
Ｐ ＝ 1
A_4 ＝ 1. 13344×10^{-6}
A_6 ＝ 5. 02843×10^{-10}
A_8 ＝ 1. 71824×10^{-13}
A_{10} ＝ 1. 87329×10^{-16}
f_1 ＝ 418. 35278
f_2 ＝-110. 00832
f_3 ＝ 223. 56611
f_4 ＝ 152. 68722
f_{34}＝ 141. 63892 。

【００４６】以上の実施例１～３の球面収差、非点収差、歪曲収差、横収差を示す収差図を図１０～図１８に示す。図中、Ｙは像高比、Ｍはメリジオナル像面、Ｓはサジタル像面を示す。

【００４７】
【発明の効果】以上説明したように、本発明によると、広い露光領域と高い解像力を持った透過率の良い、物体側及び像側共にテレセントリックな構成の縮小投影レンズを得ることができる。

【図面の簡単な説明】
【図１】本発明の実施例１の縮小投影レンズの断面図である。
【図２】本発明の実施例２の縮小投影レンズの断面図である。
【図３】本発明の実施例３の縮小投影レンズの断面図である。
【図４】本発明の実施例４の縮小投影レンズの断面図である。
【図５】本発明の実施例５の縮小投影レンズの断面図である。
【図６】本発明の実施例６の縮小投影レンズの断面図である。
【図７】本発明の実施例７の縮小投影レンズの断面図である。
【図８】本発明の実施例８の縮小投影レンズの断面図である。
【図９】本発明の実施例９の縮小投影レンズの断面図である。
【図１０】実施例１の収差図である。
【図１１】実施例２の収差図である。
【図１２】実施例３の収差図である。
【図１３】実施例４の収差図である。
【図１４】実施例５の収差図である。
【図１５】実施例６の収差図である。
【図１６】実施例７の収差図である。
【図１７】実施例８の収差図である。
【図１８】実施例９の収差図である。
【符号の説明】

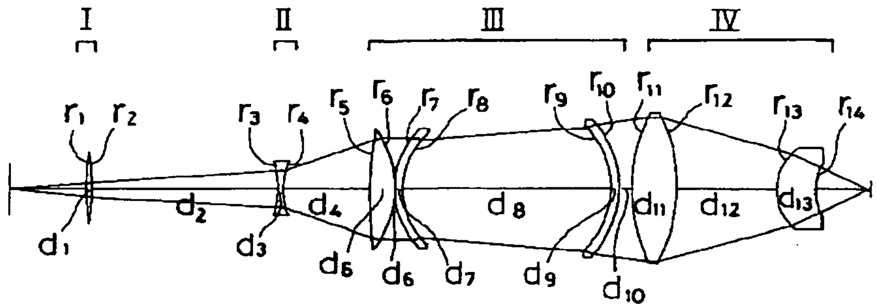
I …第１群

II …第２群

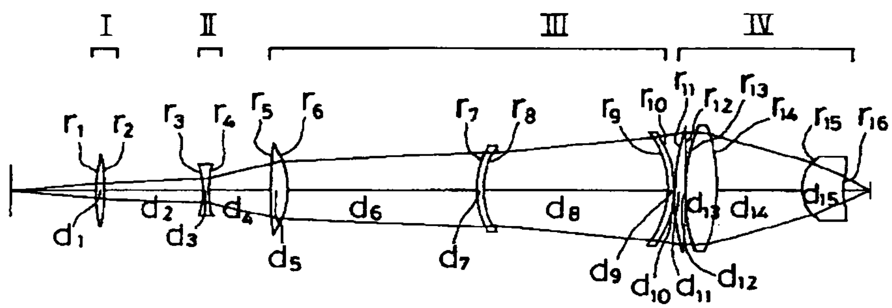
III …第３群

IV …第４群

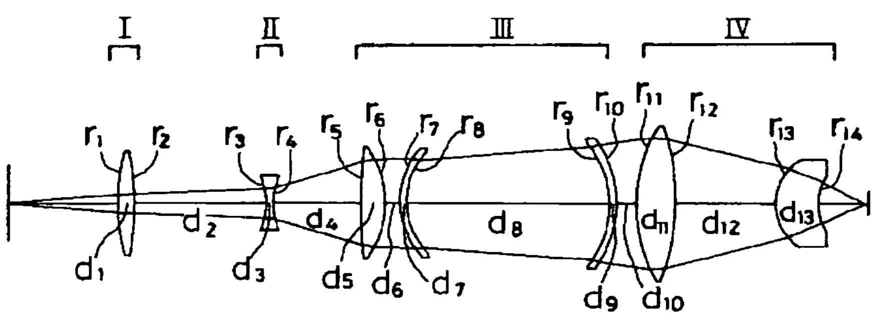
【図１】



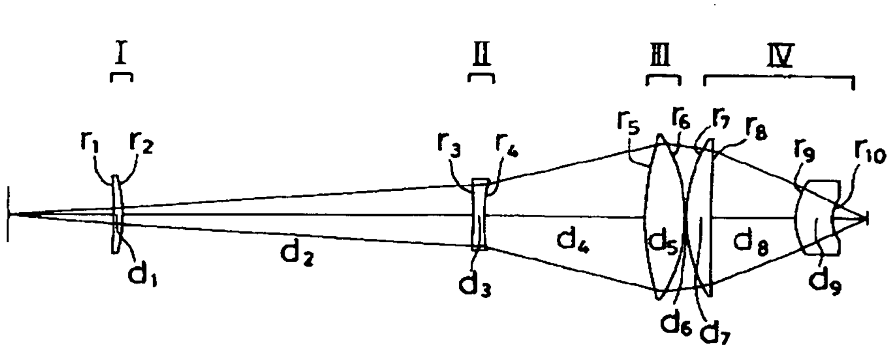
【図２】



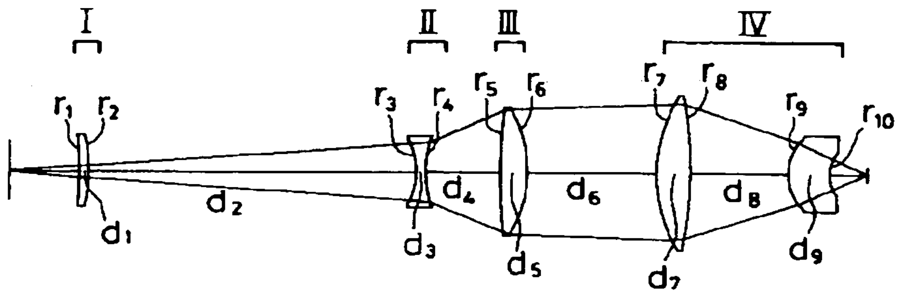
【図３】



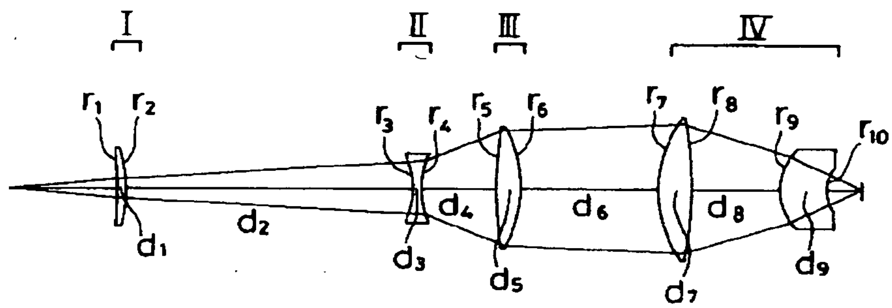
【図４】



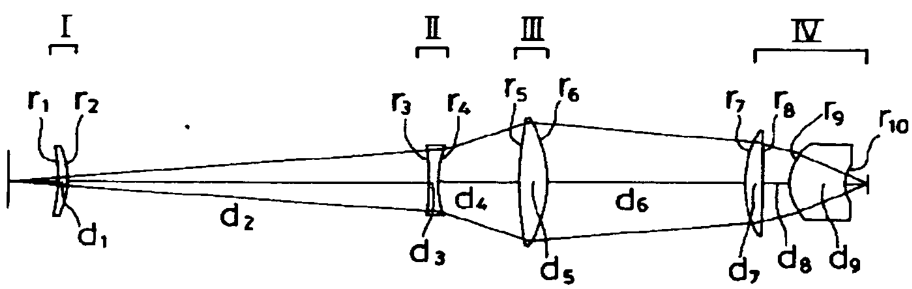
【図５】


I
II
III
IV
r1 r2
r3 r4
r5 r6
r7 r8
r9
r10
d1
d2
d3
d4
d5
d6
d7
d8
d9

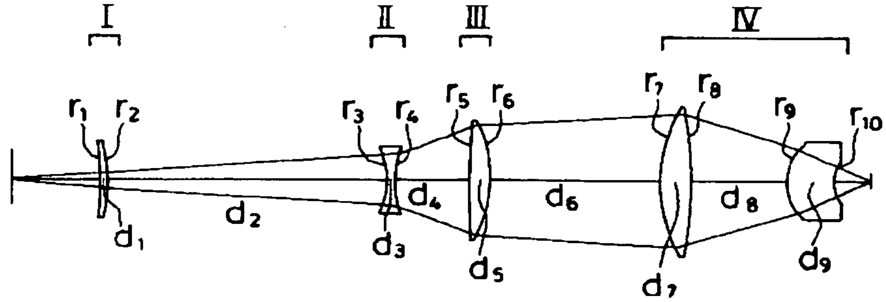
【図６】


I
II
III
IV
r1 r2
r3 r4
r5 r6
r7 r8
r9
r10
d1
d2
d3
d4
d5
d6
d7
d8
d9

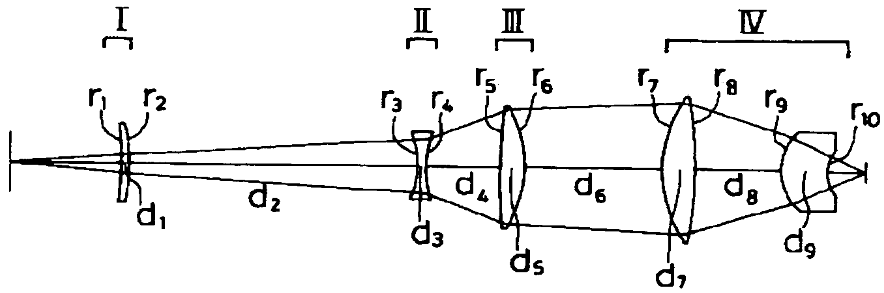
【図７】


I
II
III
IV
r1 r2
r3 r4
r5 r6
r7 r8
r9
r10
d1
d2
d3
d4
d5
d6
d7
d8
d9

【図８】

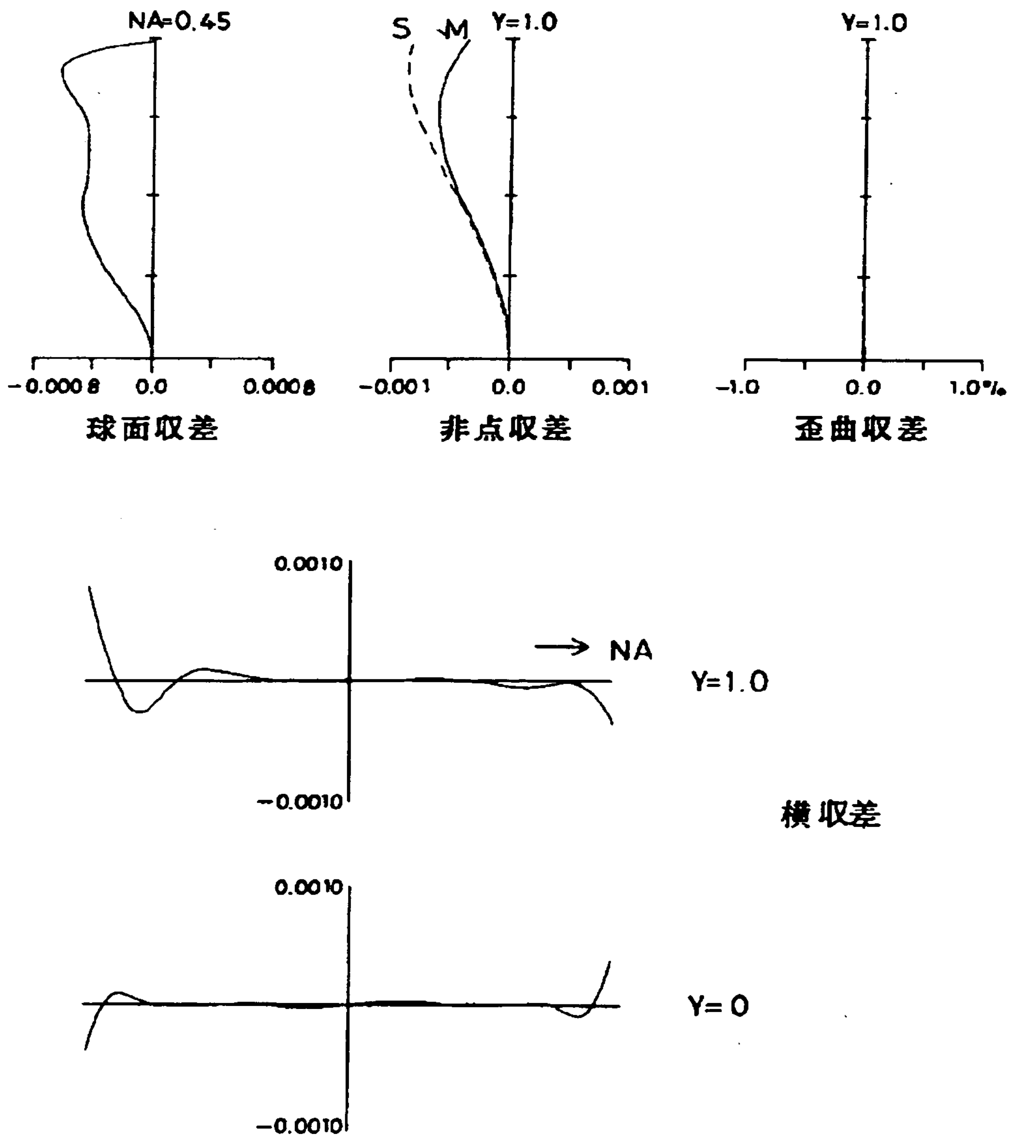

I
II
III
IV
r1 r2
r3 r4
r5 r6
r7 r8
r9
r10
d1
d2
d3
d4
d5
d6
d7
d8
d9

【図９】



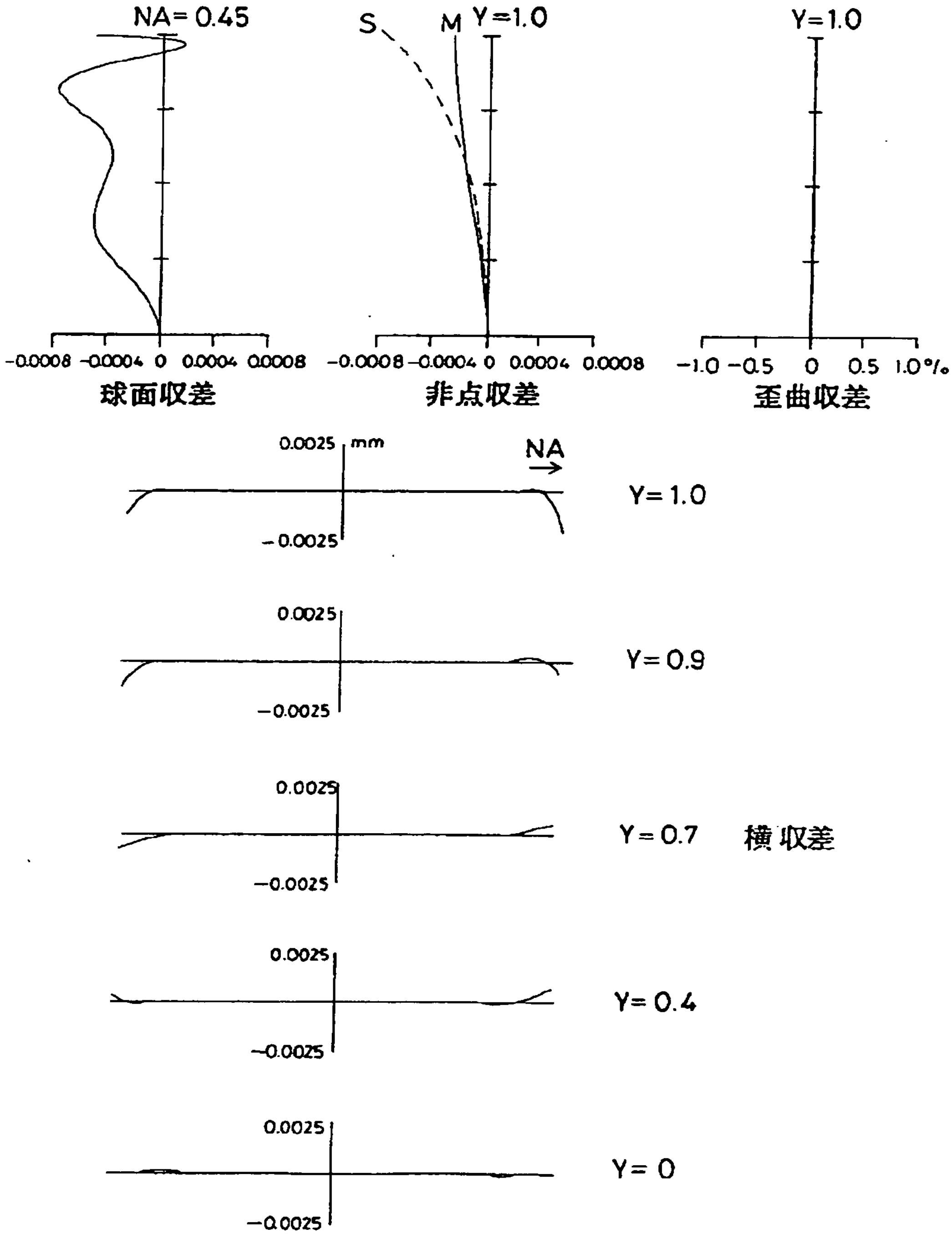
I
II
III
IV
r1
r2
r3
r4
r5
r6
r7
r8
r9
r10
d1
d2
d3
d4
d5
d6
d7
d8
d9

【図１３】

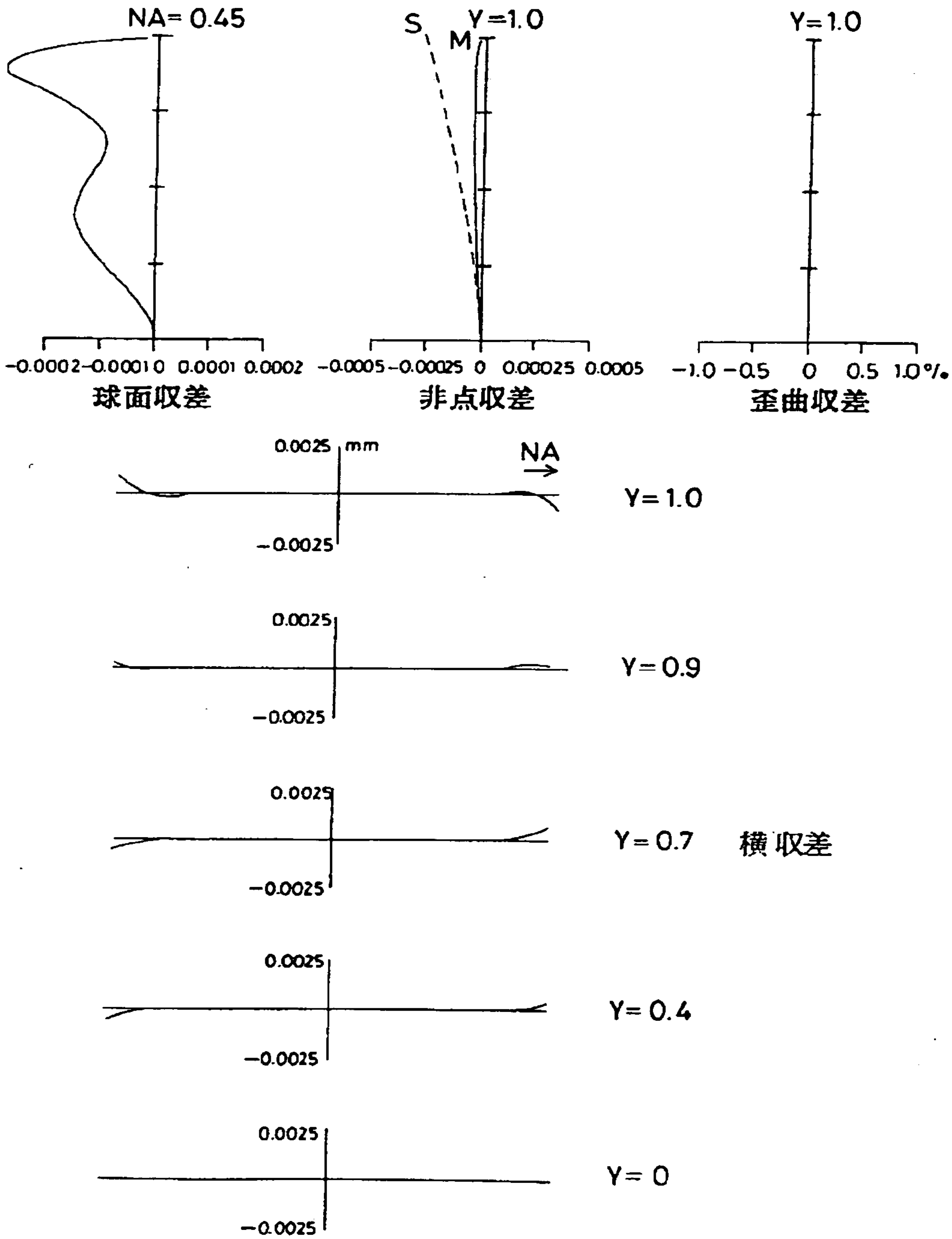


NA=0.45
S
M
Y=1.0
Y=1.0
-0.0008
0.0
0.0008
-0.001
0.0
0.001
-1.0
0.0
1.0%
球面収差
非点収差
歪曲収差
0.0010
NA
Y=1.0
-0.0010
横収差
0.0010
Y=0
-0.0010

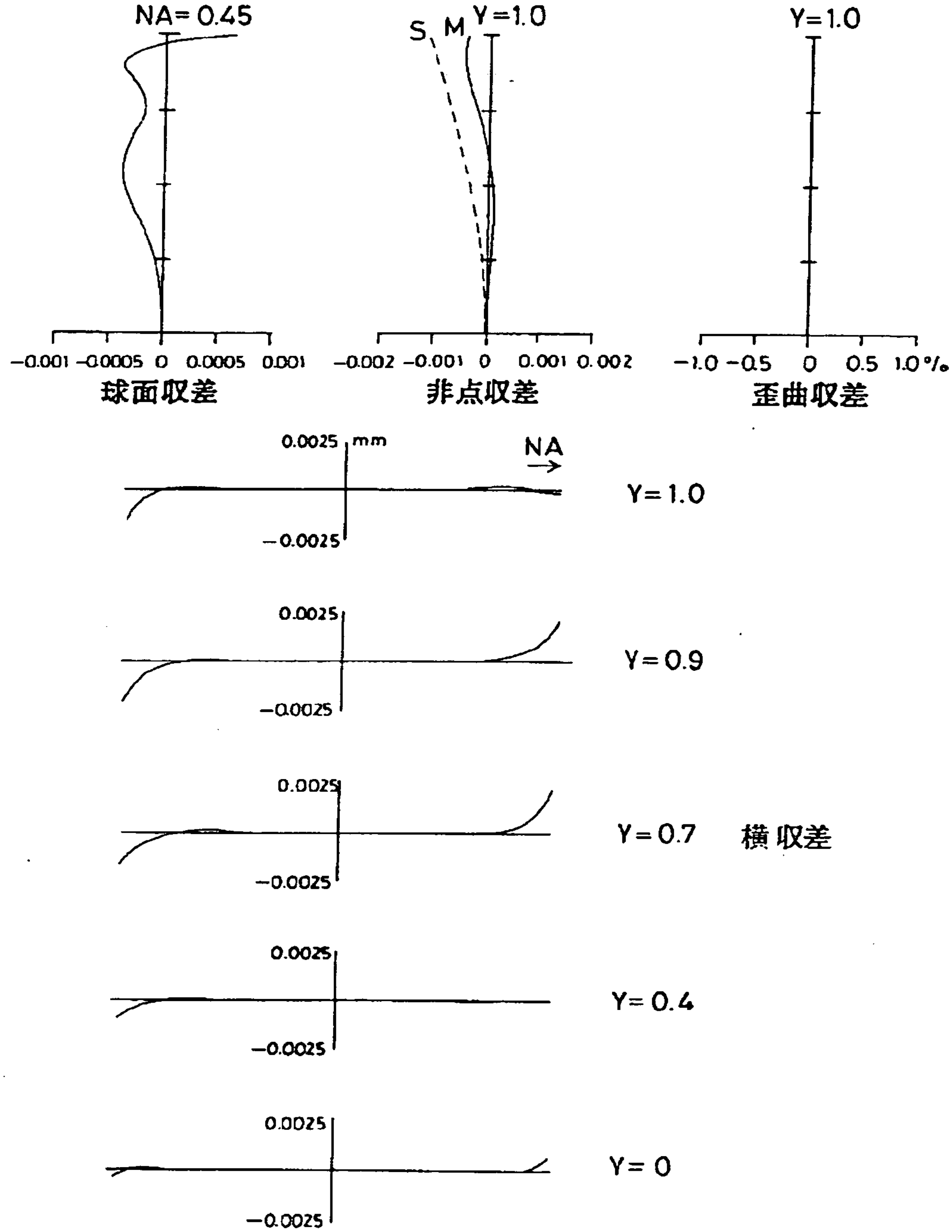
【図１０】


NA= 0.45
-0.0008 -0.0004 0 0.0004 0.0008
球面収差
S
M
Y=1.0
-0.0008 -0.0004 0 0.0004 0.0008
非点収差
Y=1.0
-1.0 -0.5 0 0.5 1.0%
歪曲収差
0.0025 mm
NA
-0.0025
Y= 1.0
0.0025
-0.0025
Y= 0.9
0.0025
-0.0025
Y= 0.7
横収差
0.0025
-0.0025
Y= 0.4
0.0025
-0.0025
Y= 0

【図１１】

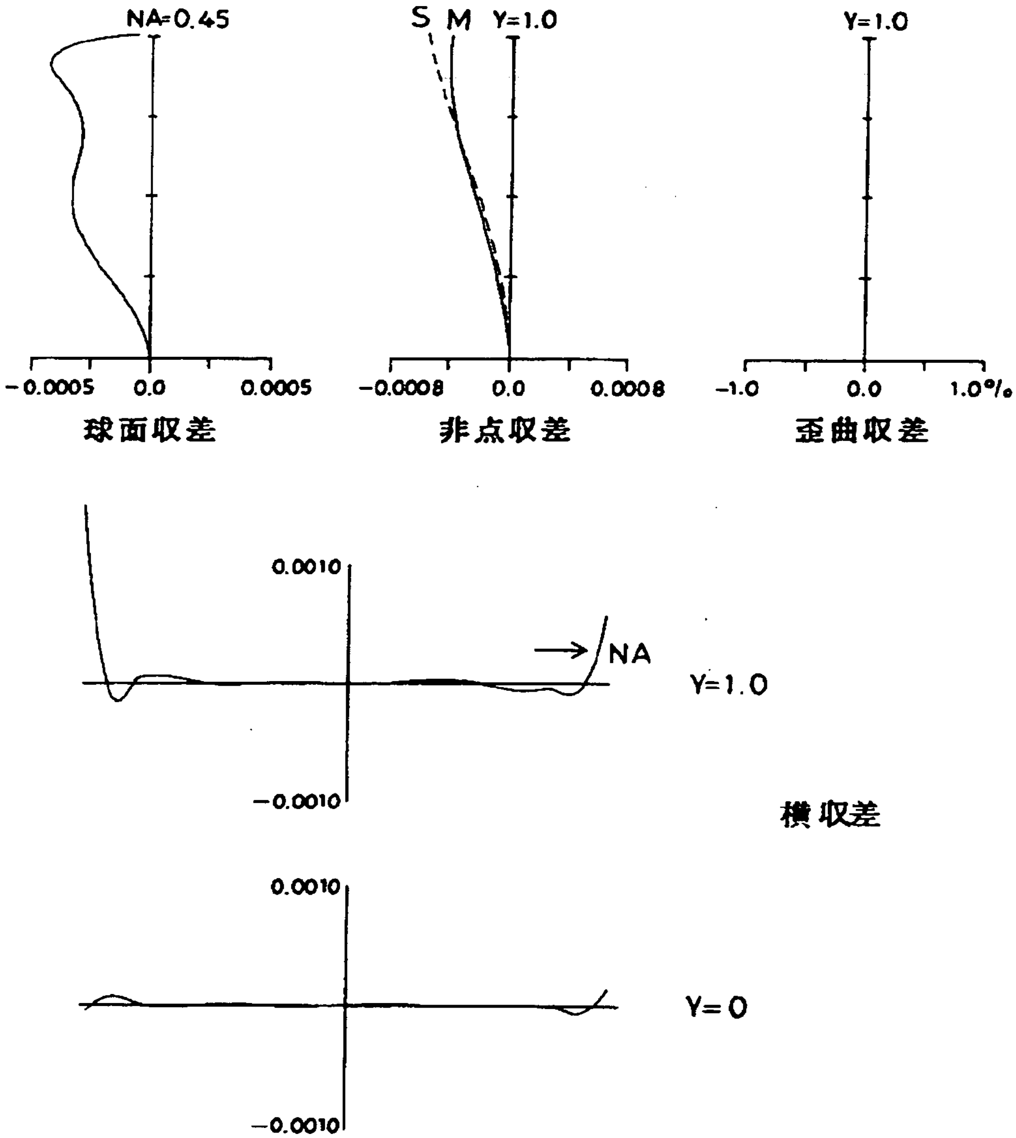

NA= 0.45
-0.0002 -0.0001 0 0.0001 0.0002
球面収差
S
M
Y=1.0
-0.0005 -0.00025 0 0.00025 0.0005
非点収差
Y=1.0
-1.0 -0.5 0 0.5 1.0%
歪曲収差
0.0025 mm
NA
-0.0025
Y= 1.0
0.0025
-0.0025
Y= 0.9
0.0025
-0.0025
Y= 0.7
横収差
0.0025
-0.0025
Y= 0.4
0.0025
-0.0025
Y= 0

【図１２】

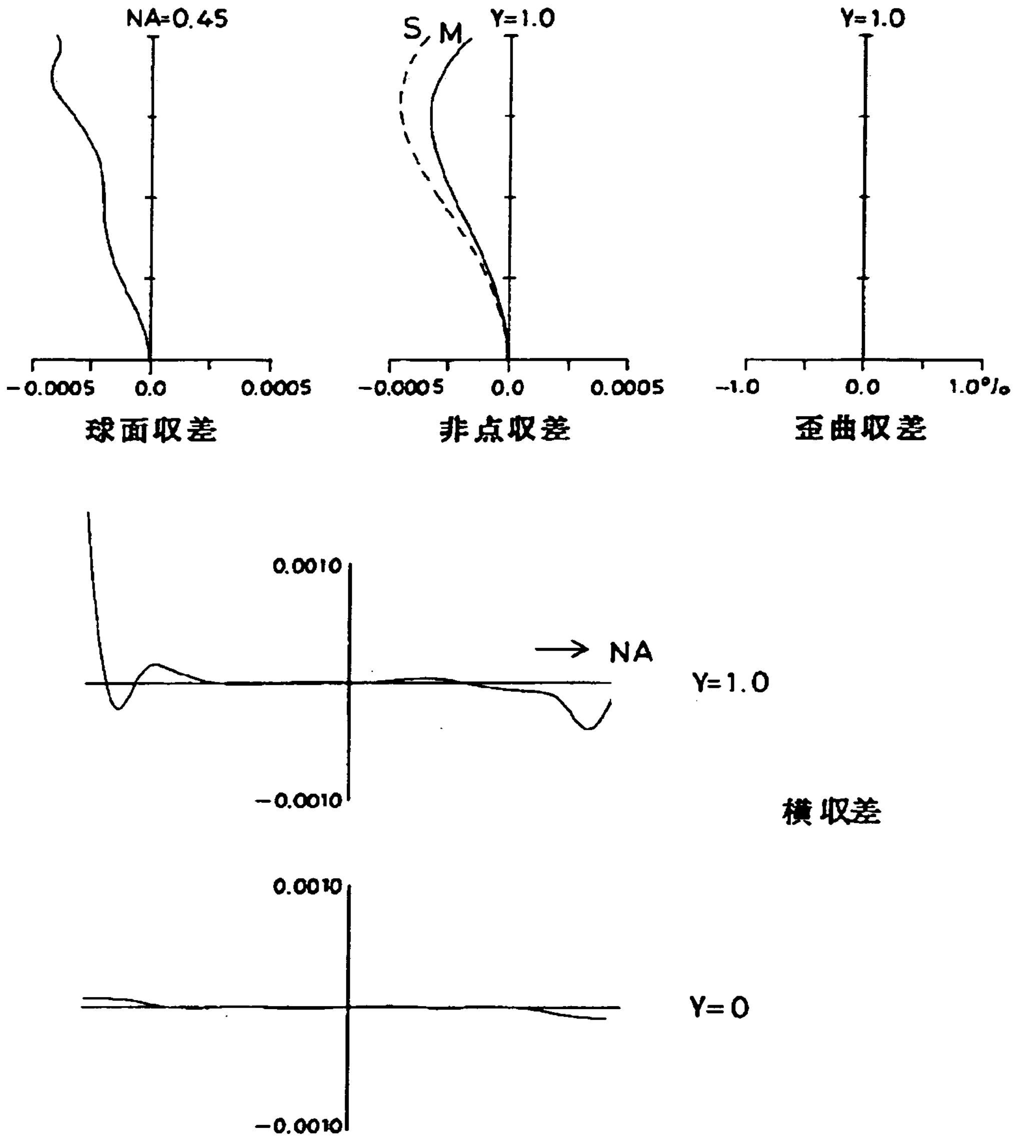


NA=0.45
S
M
Y=1.0
Y=1.0
−0.001 −0.0005 0 0.0005 0.001
球面収差
−0.002 −0.001 0 0.001 0.002
非点収差
−1.0 −0.5 0 0.5 1.0%
歪曲収差
0.0025 mm
NA
−0.0025
Y=1.0
0.0025
−0.0025
Y=0.9
0.0025
−0.0025
Y=0.7
横収差
0.0025
−0.0025
Y=0.4
0.0025
−0.0025
Y=0

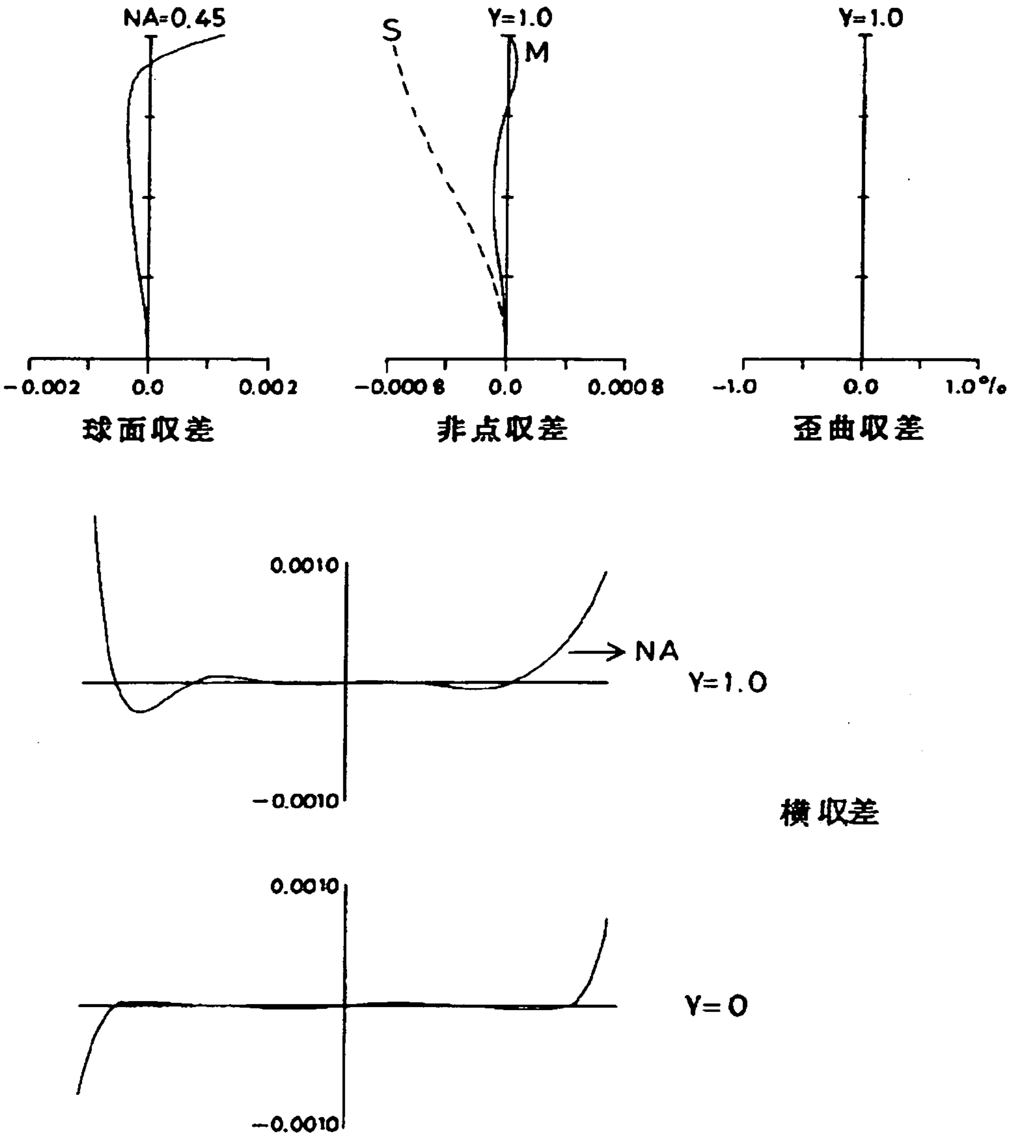
【図１４】


NA=0.45
-0.0005
0.0
0.0005
球面収差
S
M
Y=1.0
-0.0008
0.0
0.0008
非点収差
Y=1.0
-1.0
0.0
1.0%
歪曲収差
0.0010
NA
Y=1.0
-0.0010
横収差
0.0010
Y=0
-0.0010

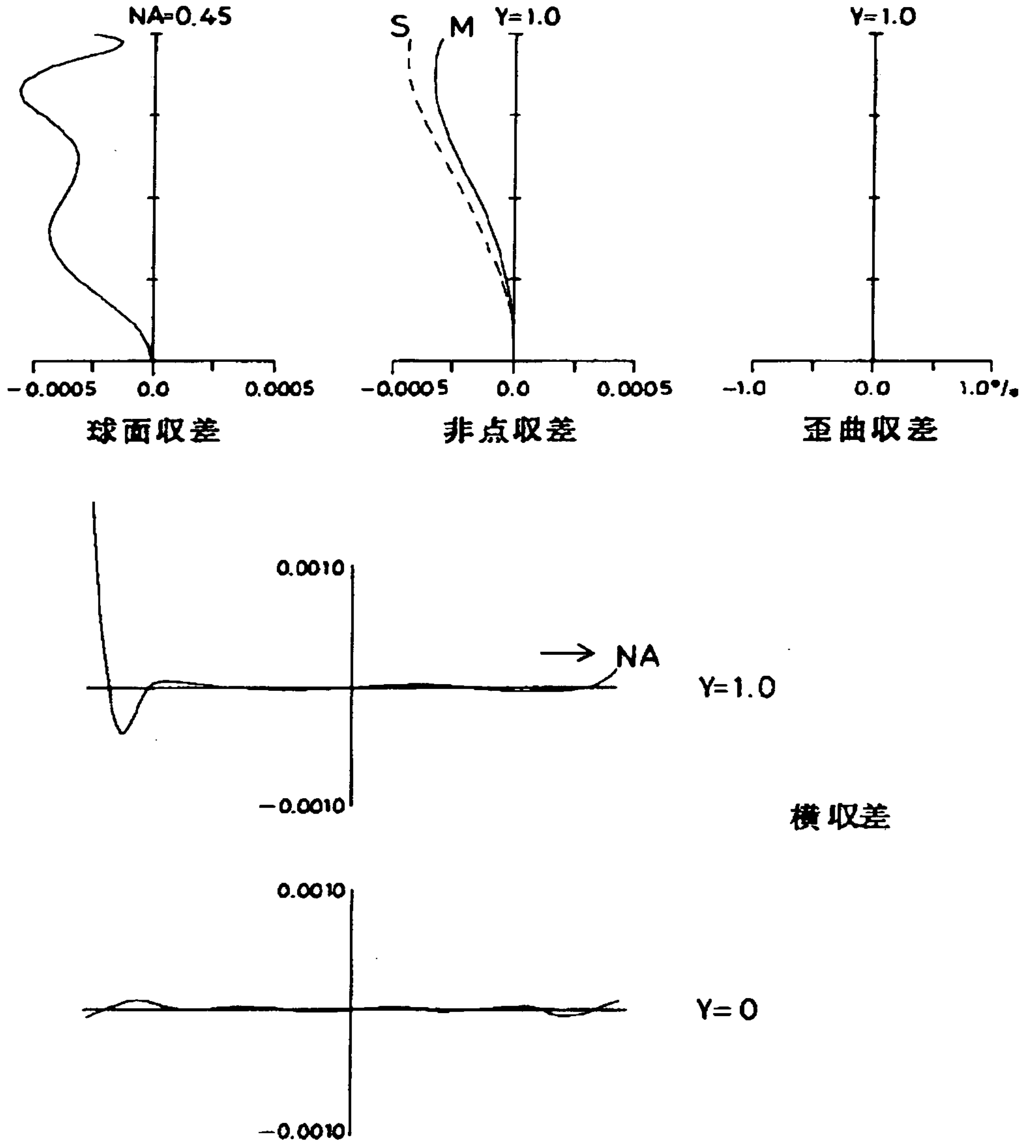
【図１５】


NA=0.45
-0.0005
0.0
0.0005
球面収差
S
M
Y=1.0
-0.0005
0.0
0.0005
非点収差
Y=1.0
-1.0
0.0
1.0%
歪曲収差
0.0010
→ NA
Y=1.0
-0.0010
横収差
0.0010
Y=0
-0.0010

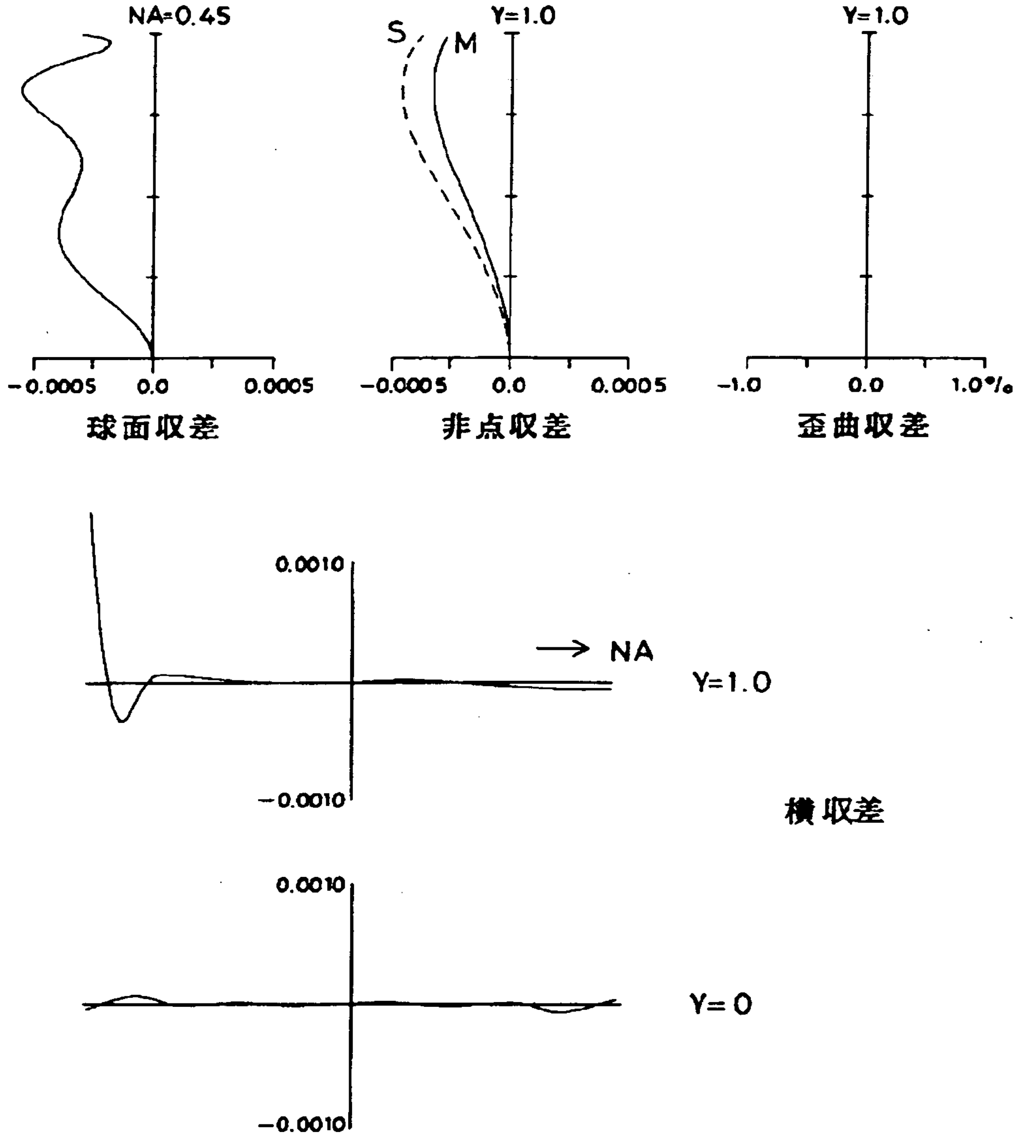
【図１６】


NA=0.45
-0.002
0.0
0.002
球面収差
S
Y=1.0
M
-0.0008
0.0
0.0008
非点収差
Y=1.0
-1.0
0.0
1.0%
歪曲収差
0.0010
-0.0010
NA
Y=1.0
横収差
0.0010
-0.0010
Y=0

【図１７】


NA=0.45
−0.0005
0.0
0.0005
球面収差
S
M
Y=1.0
−0.0005
0.0
0.0005
非点収差
Y=1.0
−1.0
0.0
1.0%
歪曲収差
0.0010
→ NA
Y=1.0
−0.0010
横収差
0.0010
Y=0
−0.0010

【図１８】


NA=0.45
Y=1.0
S
M
Y=1.0
-0.0005
0.0
0.0005
-0.0005
0.0
0.0005
-1.0
0.0
1.0%
球面収差
非点収差
歪曲収差
0.0010
NA
Y=1.0
-0.0010
横収差
0.0010
Y=0
-0.0010